Name of Dam or Reservoir	Name of Stream	Drainage Area (Sq. Mi.)	Reservoir Area (Acres)	Storage Capacity (Ac-Ft)	Crest Elevation (Ft)	Year Completed
Grizzly Valley (Lake Davis)	Big Grizzly Creek (MFFR)	44	4,000	83,000	5,785	1966
Mt. Meadows Reservoir	Hamilton Creek (NFFR)	158	5,800	24,800	5,045.7	1924
Lake Almanor	North Fork Feather River	503	28,257	442,000	4,515	1927
Lake Madrone	Berry Creek (NFFR)	14.9	25	200	1,985.5	1931
Lake Oroville	Feather River	3,611	15,500	3,484,000	922	1968
Long Lake	Gray Eagle Creek (MFFR)	1.13	141	1,478	6,531	1938
Little Grass Valley	Little Grass Valley Cr. (SFFR)	25.9		94,600		1961
Lost Creek Reservoir	Lost Creek (SFFR)	14.1		5,780		1924
Lower Three Lakes (Three Lakes)	Milk Ranch (NFFR)	1.5	44	606	6,084	1928
Palen	Antelope Creek (MFFR)	10.6	12	146	5,030	1951
Philbrook	West Branch (NFFR)			5,010		
Poe	Feather River	1,950	52	1,150	1,390	
Ponderosa	South Fork Feather River	108		4750		1958
Rock Creek	North Fork Feather River	1,700	80	4,660	2,220	1961
Round Valley	North Fork Feather River	2.17	90	1,285	5,498	1950
Silver Lake	Silver Creek (EBNFFR)	1	120	650	6,000	1877
Sly Creek	Sly Creek (SFFR)	24		65,200	3,551	1906

Name of Dam or Reservoir	Name of Stream	Drainage Area (Sq. Mi.)	Reservoir Area (Acres)	Storage Capacity (Ac-Ft)	Crest Elevation (Ft)	Year Completed
Spring Valley Lake	Rock Creek (NFFR)	.25	15	75	6,314	1961
Taylor Lake	Tributary to Indian Creek (EBNFFR)	.36	36	380	7,000	Unknown
Thermalito Afterbay	Tributary Feather River	13.3	4,550	57,500	142	1929
Thermalito Diversion	Feather River	3,640	330	13,400	233	1967
Westwood Mill Pond	Robbers Creek (NFFR)	40	112	660	5,074	1914

Table 7. Department of Water Resources Facilities

Reservoir	Storage (acre-feet)	Location
Antelope Lake	22,570	North Fork Feather Indian Creek
Frenchman Lake	55,480	Middle Fork Feather Little Last Chance Creek
Lake Davis	84,370	Middle Fork Feather Grizzly Creek
Lake Oroville	3,537,580	Feather River nr. Oroville

The Department of Water Resources operates four reservoirs in the watershed. Frenchman, Davis, and Antelope lakes are in the upper watershed. Lake Oroville, situated in the foothills near the Sacramento Valley, is the principal feature. Lake Oroville facilities also include the Thermalito Diversion Pool, the Thermalito Forebay (11,400 acre-feet), and the Thermalito Afterbay (61,100 acre-feet).

Of the many reservoirs that occur in the watershed, two have a major effect on streamflow. Lake Almanor controls flows in the upper part of the North Fork. Lake Oroville and appurtenant structures impounds the North, Middle, and South Forks Feather River near the town of Oroville.

5.1.2.7.2 Stream Discharge

The largest flows in un-dammed streams occur during the winter in response to rain, and in the spring and early summer in response to snowmelt. The lowest flows occur during late summer and early fall. The combined North and Middle Fork mean discharge to Lake Oroville is approximately 7,555 acre-feet per day, or 2.76 million acre-feet per year. Total average yearly yield to Lake Oroville is 6284 cfs for the 1969 to 2000 water years.

The table below is a list of gaging stations. Stations were chosen to represent flows of major rivers and tributaries coming into Lake Oroville.

Table 8. Gaging Stations of Streams Draining into Lake Oroville

USGS Station Number	Station Name	Period of Record	Drainage Area (mi^2)	Average Discharge (cfs)	Elevation above datum(ft)
11399500	Feather River, North Fork, near Prattville	1906-1991	493	401	4,390
11396350	South Fork Feather below Ponderosa Dam	1962-1965	108	580*	
11405300	West Branch Feather near Paradise	1957-1965	113	511`	
11404900	Feather River, North Fork, below Poe Dam, near Jarbo Gap	1967-1991	1,942	2,325	1,306
11392500	Feather River, Middle Fork, near Chico	1925-1979	686	283	4,380
11394500	Feather River, Middle Fork, near Merrimac	1951-1986	1,062	1,484	1,560

*adjusted for diversion to Miners Ranch Canal, water years 1964-65
`years 1964-65

All USGS gaging stations on the Middle Fork and its tributaries have been discontinued but there are 19 active USGS gaging stations on the North Fork and its tributaries. The lack of streamflow data on the Middle Fork is likely attributable to difficult access and the absence of hydroelectric generation.

Average monthly flows for the period of record are presented for the North Fork, Middle Fork, South Fork, and for gaging stations below Lake Oroville.

5.1.2.7.3 Yearly and Mean Monthly Streamflow below Lake Oroville

Gaging stations useful for geomorphic analyses of the lower Feather River are shown in the following table.

The Lake Oroville gage shows storage and lake level. It is useful for determining impacts on the streams draining into Lake Oroville and shoreline impacts.

The Feather River at Oroville gage is downstream of the Thermalito Diversion Dam. From 1901 to 1967, the gage recorded flows characteristic of pre- dam conditions. The annual mean flow was 5,830 cfs. After 1967, much of the flow was diverted to the Thermalito Afterbay. During most of the year, flows averaging between 500 and 600 cfs occur in the low flow section of the river between the Thermalito Diversion Dam and the Thermalito Afterbay discharge to the Feather River. The annual mean in the low flow section of the river is 1140 cfs using 1967 to 2000 water years. The pre- and post Oroville Dam mean monthly streamflow for this gage is shown in the figure below. This gage best reflects flow conditions in the low flow section between the Thermalito Diversion dam and the Thermalito Outfall.

There are five diversions from Lake Oroville and Thermalito Afterbay. These are the Palermo Canal (11406810) with an annual mean flow of 10.5 cfs, the Western Canal (11406880) with an average annual mean flow of 320 cfs, the Richvale Canal (11406890) with a flow of 127 cfs, the Pacific Gas and Electric Co. Lateral Intake 644 cfs. The average combined annual diversion from these is about 1,100 cfs. This is about 20 percent of the average annual yield of the Feather River at this point. July has the highest diversion, with the combined diversion averaging 2600 cfs (1967-98). The sum of these five mean monthly average diversions is shown in the figure below.

The Feather River near Gridley gage is about 300 feet upstream of the highway bridge and three miles east of Gridley. The record begins in 1964 and ends in 1998. No tributaries occur between the Oroville gage and Gridley, but the station reflects diversions made upstream. The pre- and post dam changes in mean monthly discharge is shown in the figure below. The Gridley station best represents flows in the Feather River between the Thermalito outfall and the mouth of Honcut Creek.

Table 9. Gaging Stations for the Feather River below Lake Oroville

GAGE NAME	NUMBER	PERIOD OF RECORD	MEAN FLOW CFS	AREA SQ. MI
Lake Oroville near Oroville	11406800	Nov. 1967-		3,607
Sum of diversions	na	Nov. 1967-	1,100	na
Feather River at Oroville	11407000	Oct. 1901-	6,280*	3,624
Feather River near Gridley	11407150	Oct 1964- 1998	4,852	3,676
Feather River at Yuba City	11407700	Oct 1964- 1984	5,812	3,974
Feather River near Nicolaus	11425000	Apr. 1942- 1983	8,140	5,921
* Adjusted yield for evaporation from Lake Oroville and diversions, 1902-2000. Annual yield from 1902 to 1967 is 5830 cfs; from 1967 to 2000 is 1140 cfs.				

The Feather River at Yuba City gage has a limited record that is not as long as the Gridley and Nicolaus gages. The average annual yields are therefore not strictly comparable. However, it does include flow from Honcut Creek and is the best gage to represent flows in the Feather River between the mouth of Honcut Creek and the mouth of the Yuba River.

The Feather River near Nicolaus gage is on the left bank 1.7 miles southwest of Nicolaus. It includes the drainages of the Yuba and Bear rivers. The gage best describes flow conditions on the Feather between the mouth of the Bear River (RM 12.3) and the mouth of the Feather at Verona. The gage ceased operation in 1983 after about 40 years of record.

5.1.2.7.4 Peak Flows

Peak flows were available for all the stream gages downstream of Lake Oroville. However, the periods of record differed for each station. The Feather River at Oroville gage has the longest period of record. Figure __, derived from the U.S. Geological Survey website, shows the peak daily flood flows for this gage. The following table shows the peak daily flow for flood years. Years without flood flows are not shown.

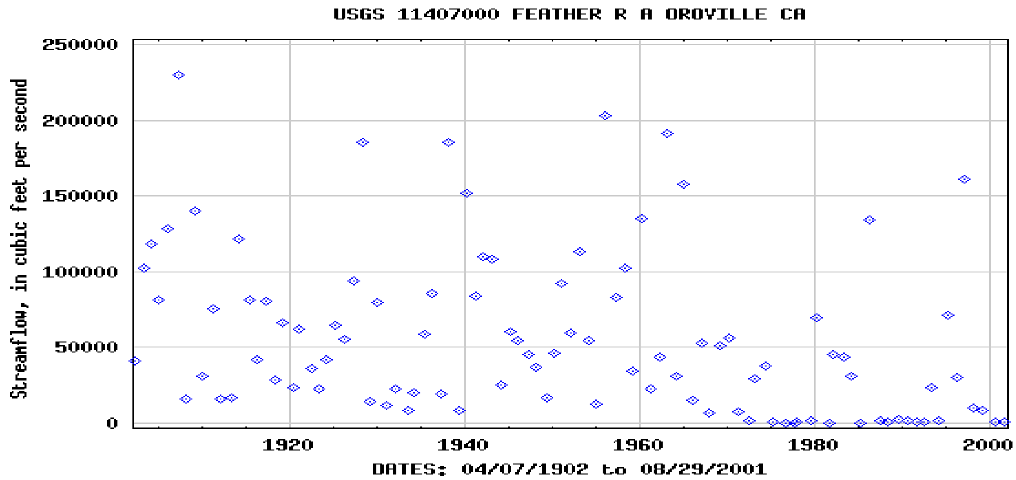


Figure 10. Peak Flows for the Feather River at Oroville Gage

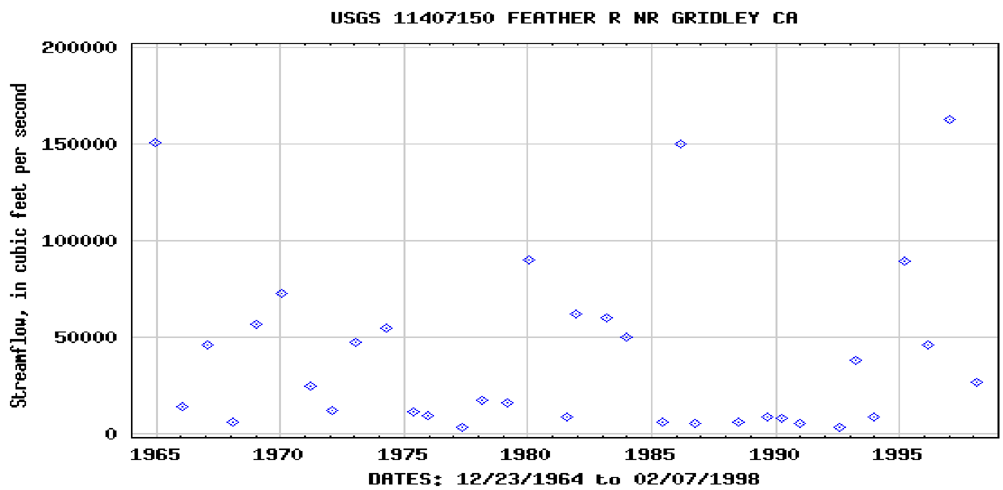


Figure 11. Peak Flows for the Feather River near Gridley Gage

Table 10. Peak Flows for Feather River Gaging Stations

CALENDAR YEAR	Oroville * 11407000	Gridley 11407150	Yuba City 11407700	Olivehurst 11421700	Nicolaus 11425000
1903	102	-	-	-	-
1904	118	-	-	-	-
1906	128	-	-	-	-
1907	230	-	-	-	-
1909	140	-	-	-	-
1913	122	-	-	-	-
1928	185	-	-	-	-
1937	185	-	-	-	-
1940	152	-	-	-	-
1942	110	-	-	-	-
1943	108	-	-	-	-
1953	113	-	-	-	127
1955	203	-	-	-	357
1958	102	-	-	-	-
1960	135	-	-	-	136
1963	191	-	-	-	264
1964	158	151	182	-	281
1967	53.3	45.6	52.8	-	96.6
1969	51.1	56.4	48.1	-	88.4
1970	56.3	72.9	74.5	133	146
1973	29.7	47	54.6	62.1	72
1974	37.8	54.7	55.3	88	108
1980	69.5	90.1	-	105	115
1981	45	61.8	-	-	148
1983	43.5	60	-	-	112
1986	134	150	-	-	-
1993	23.4	37.7	-	-	-
1995	71.7	89.4	-	-	-
1996	30.2	45.7	-	-	-
1997	161	163	-	-	-
1998	10.2	26.4	-	-	-

NOTE: Calendar years; highest daily flow in 1,000s of cfs
- No data;
* 1901- 1967: Pre-Oroville Project minimum flood flow recorded in table is 100,000 cfs;
1967- Post Oroville Project minimum flood flow recorded is 10,000 cfs

5.1.2.7.5 Yearly and Mean Monthly Discharge below Lake Oroville

5.1.3 Large Scale Geomorphic Practices

"Compile and summarize information on large-scale geomorphic processes and disturbances within the watershed downstream of Oroville Dam. These include large flood events, volcanic eruptions, and mass movement. Information will also include human-induced events, such as deforestation, hydraulic mining, urbanization, dam building, diversions, and others."

Prior to the 1850s, resource use in the watershed was limited. Local Native Americans lived in the area and hunted and fished. Their activities did little to change the natural environment although they were known to use fire to clear forest areas. Major resource use began in the watershed in the 1850s, and included livestock grazing, road building, timber harvesting, mining, and farming. Recent activities also include local urban development and varied recreational uses. Land use in the study area includes timber harvesting, grazing, agriculture, recreation, mining, and hydroelectric development.

5.1.3. 1 Large Flood Events

Table 11. Large Flood Events

(In Progress)

Table 11. Peak Flows of Historic Floods

Oroville Gauge	Peak Flow $^{m3}/_{s}$	$^{ft3}/_{s}$
March 1907	6513	(230,000)
March 1928	5975	(211,000)
December 1937	5239	(185,000)
February 1940	4304	(152,000)
December 1955	5748	(203,000)
January 1963	5409	(191,000)
December 1964	4474	(158,000)
Post-Dam Peaks		
January 1970	1509	(53,000)
January 1980	1832	(64,000)
April 1982	1614	(57,000)

Copied from the DWR "*1982 Feather River Spawning Gravel Baseline Study*"

5.1.3.2 Volcanic Eruptions

(In Progress)

5.1.3.3 Mass Movements

Pre-historic landslides large enough to temporarily block the North Fork may have occurred. No basin-wide landslide investigation has been done in the Feather River drainage.

A 30,000 cubic yard landslide damaged two PG&E hydroelectric powerhouses and related equipment costing $40 million to repair (Sacramento Bee, February 26, 1985). The landslide occurred at the Caribou powerhouse and Belden Reservoir on the North Fork Feather River.

Numerous landslides occur along the Feather River and its major forks. Failures in this watershed are largely within volcanic and metamorphic rocks. The toes of a number of these landslides are now seasonally inundated by Lake Oroville. Landslide movements are mostly prehistoric. However, several failures indicate recent activity (DWR, 1979). A large "dormant" landslide (approximately three square miles) is on the north slope of Bloomer Hill, directly above the North Fork in the Lake Oroville reservoir. The toe has recently been reactivated in places. Catastrophic movement of this landslide is a public policy concern because of its potential disastrous effect on the Lake Oroville.

Rock units with a history of slope instability in the watershed are the metamorphic "greenstone" belt on Quincy road, serpentinite and talc schist, Tertiary non-marine gravel, and Tertiary pyroclastic rocks, especially those with high clay contents (USFS, 1988).

5.1.3.4 Agriculture

Agriculture is practiced on private lands throughout the watershed but is concentrated on valley land. Flat valley land contains deeper, more productive alluvial soils that are easier to cultivate and irrigate. Most irrigation diversion is for hay and pasture production. Sierra Valley, in the upper Middle Fork watershed, has large areas cultivated seasonally during the last 100 years. Alfalfa, winter wheat, oat, hay, and other forage types are the major crops grown. Within the Sacramento Valley, rice and fruit-nut orchards are the principal agricultural land uses along the Feather River

5.1.3.5 Timber Harvesting

The North and Middle Fork Feather River watersheds provide favorable conditions for timber production. The area has considerable climatic and biologic variety resulting in a productive and extensive forest. The timber industry grew from a few sawmills in the 1850s to a major industry in the watershed but has declined significantly since the late 1980s. Timber harvesting occurs on both public and private land.

The U.S. Forest Service has managed the public's timber resources since its establishment in 1910. The Plumas National Forest has jurisdiction over a total of 1,828 square miles with 1,606 square miles in the study area. Plumas National Forest includes 53 percent of the North Fork Feather River watershed and 44 percent of the Middle Fork Feather River watershed. The PNF historic average for timber sold per year is 190 million board feet. In the last few years, timber sold is expected to be less, because of cuts in congressional funding and changing environmental management policies. Small portions of Lassen National Forest and Tahoe National Forest are also contained within the study area but constitute a small percentage of the total watershed.

Private timber harvesting comprises significant land use in the watershed. The Collins Pine Company has access to a large block of private timberlands. For the past several years, annual production from the Collins' Almanor Forest has nearly equaled timber production of the national forest (DWR, 1988).

5.1.3.6 Grazing

Montane Meadows and large valleys provide favorable range for livestock grazing and production. Grasses grow abundantly during the spring and near streams during the entire summer.

Horse, sheep, and cattle grazing began during the gold rush years. "The late 1800s and early 1900s saw intensive sheep grazing on the upland areas and high meadows, while intensive cattle grazing was occurring in the large meadows" (USFS, 1989). Many of the valley and streamside meadows are privately owned and are used for year-long livestock grazing.

The Plumas National Forest provides summer range for livestock operations during a 4.5 month period from June to mid-October using grazing permits. As of 1986, about 314,500 acres (27 percent) of the total 1,168,517 forest acres were classified as suitable for grazing activity. Of this available grazing land, about 71 percent was managed under a continuous grazing system, 27 percent was managed with a deferred system (grazing was deferred until plants reached seed maturity), and just 2 percent was managed with a rest-rotation system. During 1981, approximately 7,500 cattle and 1,400 sheep grazed on land in the Plumas National Forest (USFS, 1986). Similar figures are not available for private land and other national forest land constituting about 50 percent of the total watershed area.

5.1.3.7 Recreation

For local economies, revenues from recreational activities have begun to rival those of other land use activities. The Feather River watershed offers mountains, lakes and streams. Recreational activities include fishing, hunting, hiking, bike riding, horseback riding, camping, nature photography and study, swimming, boating and water skiing, gold panning and dredging, off-road vehicle and snowmobile use, and cross-country skiing. There are many recreational facilities, both public and private. Recreation in Plumas National Forest has generally increased since the 1950s. Recreation visitor days were 2.3 million in 1982, which grew 12 percent to 2.6 million by 1992 (USFS, 1994). The USFS projects that recreation demand will increase at the current population growth rate in the region, reaching 4.6 million recreation visitor days by 2030 (USFS, 1986).

Lake recreation is available at numerous lakes, the most significant of which are Lake Almanor and Lake Oroville. Camping, boating, and fishing are the primary recreational pursuits.

Fishing and bird hunting are also important recreational opportunities along the lower Feather River. Some boating also occurs, but low flows during much of the year restrict usage.

5.1.3.8 Mining

Mining in the watershed began in the mid-1800s and continues today, although on a smaller scale. Mineral resources include gold, copper, manganese, silver, chromite, lead, limestone, sand, gravel, and rock. The first miners exploited placer gold deposits in stream gravel. Gravel was dredged and sluiced to separate the gold. Between the 1850s and 1890s, large amounts of sediment were washed into the stream system using high-pressure water jets to erode older gold-bearing formations.

Hard rock mining also produced large quantities of pulverized tailings. Many of these tailings now leach sulfides, which lower stream water pH. Sulfide contamination, by lowering pH, may significantly harm fisheries.

Dredging for placer gold occurred over large areas of what is now the Oroville Wildlife area. Windrows of gravel still remain although considerable gravel has been harvested for the construction of Oroville Dam and appurtenant facilities. Commercial gravel mining is also occurring in the area.

5.1.3.9 Hydroelectric Development

The North Fork Feather River is extensively developed for hydroelectric power. About 720 megawatts are generated by Pacific Gas and Electric (Table 3) along the reach from Lake Almanor to Lake Oroville. The North Fork is advantageous for hydroelectric generation because of steep gradients, a large reservoir located high in the watershed, abundant snowfall, and high annual discharge.

Table 12. Hydroelectric Generating Plants on the Feather River above Lake Oroville

HYDROELECTRIC GENERATING PLANTS	YEAR OPERATION BEGAN	FLOW AT NORMAL OPERATING CAPACITY (cfs)	NORMAL OPERATING CAPACITY (megawatts)
Hamilton Branch	1921	200	4.8
Butt Valley	1958	1,620	40.0
Caribou No. 1	1921	1,114	75.0
Caribou No. 2	1958	1,464	120.0
Belden	1969	2,410	125.0
Rock Creek	1950	2,880	112.0
Bucks Creek	1928	340	57.5
Cresta	1949	3,510	70.0
Poe	1958	3,700	120.0
Big Bend	1909	*	*

* Big Bend generating plant was inundated by Lake Oroville in 1968.

PG&E regulates releases from Lake Almanor on the North Fork throughout the year. Downstream of Lake Almanor a series of impoundments divert streamflow through tunnels and penstocks to hydroelectric generators. The major hydropower storage reservoirs from upstream to downstream include Mountain Meadows Reservoir, Lake Almanor, Butt Valley Reservoir, Rock Creek and Cresta Reservoirs, and Bucks Lake. The table below lists the PG&E powerhouses on the North Fork.

DWR has Antelope Lake, Frenchman Lake and Lake Davis but none of these have any hydroelectric development. Lake Oroville's Hyatt power plant, the Thermalito diversion power plant, and the Thermalito power plant have a combined maximum generating capacity of about 850 megawatts

Human-induced changes to the Feather River, including bank protection, gravel dredging and mining, riparian vegetation removal, dams, flow regulation, and flood control, have resulted in a number of physical and ecological effects. Primarily, the loss of gravel recruited from reaches upstream from Oroville Dam, has reduced the spawning gravel available in downstream reaches.

The effect of Oroville Dam on the magnitude of flood flows is dramatic. Table I shows several historic pre-dam peak flows (1907-1964), and post-dam peaks (1970-1995). The average of the peaks of seven major pre-dam flood events was 190,000 cfs. The average of 8 post-dam peaks through winter 1995-96 is about 74,000 cfs. Only one event, a February 1986 peak of 150,400 cfs approached the historic pre-dam high flows.

The two factors most responsible for reducing spawning gravel quality in the reach are the loss of gravel recruitment from areas above Oroville Dam and scour of spawning sized gravel by flood flow releases from Lake Oroville. Another factor acting downriver from the reservoir is the restriction of the Feather to a narrow leveed channel where it is unable to rework and recruit gravel material on the old natural floodplain.

Historically, gravel was mined directly from the Feather River, but now most of the mines are in off-stream areas of the historic flood plain.

It is a well-documented fact that dams reduce spawning gravel quality by capturing spawning gravel in the reservoirs. Because flood flows in the Feather River below Oroville Dam are still high enough to transport spawning size gravel, and since no new gravel is coming in from areas above, the gravel at some spawning riffles has a natural tendency to become coarser and coarser until stable armored layers become established.

5.1.4 Watershed Instability, Erosion, and Sediment Sources

"Identify the major sediment sources in the watershed and amount of sediment produced by the North, Middle, and South Forks."

The upper Feather River watershed is producing high sediment yields. High sediment yields are caused by accelerated erosion. A U.S. Soil Conservation Service report, *East Branch North Fork Feather River Erosion Inventory Report* (1989), estimated that ninety percent of erosion in a 1,209 square mile study area was accelerated erosion. Accelerated erosion is a soil loss rate greater than natural geologic conditions and is caused by such human activities as road building, timber harvesting, overgrazing livestock, and agriculture. High sediment yield can reduce reservoir capacity, degrade water quality, and harm fish and wildlife. High sediment yields have significantly impaired storage capacity and hydroelectric operations in several reservoirs upstream of Lake Oroville on the North Fork Feather River.

A large amount of sediment is captured by reservoirs upstream of Lake Oroville. Lake Oroville captures most of the remaining sediment. This amount has been estimated to be in the neighborhood of about 500 acre-feet per year. This in turn results in a sediment-starved river system below the dam. It is estimated that the trap efficiency of the reservoir is above 97 percent. A portion of silt and clay is discharged to the Feather River below the dam, but no pebbles, gravel, or cobbles. High flows below the dam have scoured the streambed, resulting in coarsening and armoring of salmon spawning riffles as far downstream as Honcut Creek.

Past watershed instability, erosion, and sedimentation investigations have focused largely on tributaries of the North Fork with little attention to the Middle Fork watershed. This focus on the North Fork and its tributaries reflects concern over excessive sedimentation and increased maintenance effectively reducing the operating efficiency and life span of reservoirs and power plants. Landslides cause increased sedimentation and downstream cumulative effects. Erosion and downcutting of streams lowers groundwater levels and dewaters meadows. Reduced stream flow in the late summer and fall from dewatered meadows reduces hydropower generation capability. The dewatering of meadows has also resulted in a transformation from perennial grasses to dryland vegetation such as sagebrush.

4.3.1.1 Instability

Landslides are a major source of sediment in the watershed. The western portion of the watershed is most sensitive to this hazard, particularly the canyons of the Feather River and canyons of Indian, Spanish, and Eureka creeks (USFS, 1986). Pre-historic landslides large enough to temporarily block the North Fork may have occurred. No basin-wide landslide investigation has been done in the Feather River drainage.

A 30,000 cubic yard landslide damaged two PG&E hydroelectric powerhouses and related equipment costing $40 million to repair (Sacramento Bee, February 26, 1985). The landslide occurred at the Caribou powerhouse and Belden Reservoir on the North Fork Feather River.

Numerous landslides occur along the Feather River and its major forks. Failures in this watershed are largely within volcanic and metamorphic rocks. The toes of a number of these landslides are now seasonally inundated by Lake Oroville. Landslide movements are mostly prehistoric. However, several failures indicate recent activity (DWR, 1979). A large "dormant" landslide (approximately three square miles) is on the north slope of Bloomer Hill, directly above the North Fork in the Lake Oroville reservoir. The toe has recently been reactivated in places. Catastrophic movement of this landslide is a public policy concern because of its potential disastrous effect on the Lake Oroville.

Rock units with a history of slope instability in the watershed are the metamorphic "greenstone" belt on Quincy road, serpentinite and talc schist, Tertiary non-marine gravel, and Tertiary pyroclastic rocks, especially those with high clay contents (USFS, 1988).

5.1.4.1 Watershed Instability and Erosion

The watershed within the Plumas National Forest has been mapped and ranked for erosion hazards by USFS for planning purposes. Department of Water Resources (1992) obtained the information from USFS and used it to prepare an Erosion Hazard Map.

The map shows the potential for erosion hazard and landslide activity in the Plumas National Forest part of the watershed. Two land stability risk classifications used by Plumas National Forest, Low Risk and Moderate Risk, were combined as Class I, Low to Moderate Risk. Class I typically represents gentle to moderately steep (<60%) sloped lands with few signs of naturally caused slope instability. Class II, High Risk, represents steep slopes with visible signs of naturally caused slope instability. Class III, Extreme Risk, represents lands that are usually very steep (>75%) and show evidence of recent landslide occurrence. Risk areas were digitized from Plumas National Forest data using an Autocad computer program. The resources used by the USFS contractors to compile the original Risk Maps at 1:24,000 scale include: 1) slide feature maps from aerial photo interpretation; 2) slope maps, geologic maps, soils maps, aerial photos, and site specific landslide information from existing engineering geology reports, and; 3) personal observations of USFS personnel.

Streambank erosion information was obtained from a Soil Conservation Service report, *East Branch North Fork Feather River Erosion Inventory Report* (SCS, 1989). The area covered by that report includes all of the East Branch and three other sub-watersheds of the North Fork Feather River. Streams, with sediment production of 600 tons per square mile or more, were highlighted.

The Instability and Erosion Hazard Map is only complete in Plumas National Forest for about 50 percent of the study area. Minimal data exist in parts in Lassen and Tahoe National Forests or on private land

Table 13. Sediment Yield to Rock Creek Reservoir (SCS, 1989)

Sub-watershed Number *	Sub-watershed Name	Tons per Sq. Mile
12	Above Antelope Lake	2,120
3	N.F. Feather River	1,760
9	Wolf-Round Valley	1,650
5	Upper Spanish-Rock	1,300
6	Lower Spanish	1,160
13	Last Chance	1,110
11	Hungary-Mid. Indian	1,110
7	Greenhorn	1,050
15	Red-Clover Dixie	830
8	Little Grizzly	770
4	Rush-Mill	760
10	Lights-Cooks	730
14	Squaw Queen	660
1	Chips-Yellow	610
2	Butt Valley Res.	0

* Sub-watersheds are ranked in descending order of sediment yield in tons per square mile. Sub-watershed numbers are keyed to ArcView GIS coverages.

The greatest erosion effects occur on the East Branch of the North Fork Feather River. The deteriorating condition is evident with gully formation and channel down-cutting occurring on a large scale in the broad alluvial valleys in the upper part of the watershed.

Table 4 below presents sediment data from sub-watersheds within the East Branch watershed. The sub-watersheds are shown in Figure 11. These data were obtained from the Soil Conservation Service report *East Branch North Fork Feather River Erosion Inventory Report* (1989), written in cooperation with the Feather River Coordinated Resource Management Group.

5.1.4.1.1 Landslides at Lake Oroville

Numerous landslides exist along the banks of Lake Oroville. These are shown on ArcView GIS coverage of the Lake Oroville area. The landslides occur in granitic and metamorphic rocks that form the hills and valleys of the westernmost portion of the Sierra Nevada. Many of the landslides continue out-of-site into the depths of the reservoir. It is common for the motion to occur along joint and/or fracture planes, especially in the granitic rocks.

The landslides were mapped using aerial photography and then confirmed in the field. Field conformation included boating up to each slide looking for scarps, rubble and debris, lobes at the base (low lake levels made this possible), any other signs of movement, and walking the boundaries if necessary. Some of the landslides were taken from previously completed DWR landslide maps. The type of motion on each landslide was determined and then classified as ancient, active or inactive (Buer and Senter 1982).

Active landslides display evidence of recent movement, such as fresh barren scarps, jackstrawed trees, displaced roads and stream channels, and clusters of large rocks in stream channels or lake shore. Vegetation on active landslides is typically sparse, with willow, grass, and brush predominant.

Inactive landslides have well-developed and easily recognized slide topography. Bowl- or spoon-shaped depressed areas are bounded by steep crown and flanking slopes. Flat lobes and irregular hummocky topography are well defined. Depressed sags and ponds, water seeps, and water-loving vegetation are common. Vegetation is generally a well-established, mature forest stand but may vary in type and density from surrounding stable areas. Trees with bowed trunks occur. This feature may indicate that deep-seated movement is presently occurring at slow rates. Inactive landslides define areas of past instability and indicate sensitivity to erosion and mass wasting.

Ancient landslides have indistinct boundaries and subdued landslide form. Crown and flanking slopes are rounded and ill-defined. Sags and ponds are typically absent. These landslides usually are covered by well-established, mature stands of the same age class as the surrounding forest. The lack of well-defined features and boundaries suggests that many hundreds—perhaps thousands—of years have passed since active movement occurred. Ancient landslides outline zones where deep soil and disturbed rock can be expected to be sensitive to management projects. Roads that cross both inactive and ancient landslide areas commonly have cut-and-fill slope failure problems associated with clay soils and high water tables.

The area of all the confirmed landslides mapped around Lake Oroville is approximately 3,996 acres. Of that 301 acres (8%) are active, 525 acres (13%) are inactive, and 3,196 acres (79%) are ancient landslides. There is also linear 75,282 feet of landslide material along the shoreline of the lake.

The majority of the active landslides are a result of reactivation of inactive or ancient landslides. There are also a significant number of small active landslides that are due to bank/toe failure at the edge of the reservoir, especially on the Middle Fork. These are likely caused by the repeated wave action along the shoreline under cutting already unstable areas.

The majority of the active, inactive, and ancient landslides (42%) are found in the arc complex rocks. The arc complex rocks contain 42% of the total landslide acreage (the majority of the active, inactive, and ancient landslides), metasedimentary rocks contain 20%, mélange contains 12%, Smartville ophiolite contains 12%, intrusive rocks contain 9%, and metavolcanic rocks contain 5%.

5.1.4.2 Sediment Sources

5.1.5 River Classification

"Classify downstream reaches, using the Rosgen stream classification system. The reaches will be classified using Rosgen's Level I stream typing, and then further classified using the Level II or higher classification based on channel form and substrate. The location of bank protection structures, levees, 100-year floodplain and other river data will also be collected. The results of the stream classification and data collection will be incorporated into the GIS system."

5.1.5.1 Rosgen Level 1 Stream Typing

Table 14. Mesohabitat from Oroville to Yuba City

Habitat Type	Area (ft2)
Backwater	3,209,675
Boulder Run	30057
Glide	28,748,554
Pool	22,371,508
Riffle	4,089,226
Run	2,883,999
Total	61,333,019

Mesohabitat mapping from the Fish Diversion Dam below Lake Oroville to Yuba City has been completed. The field measurements included recording the location of riffles, runs, glides, pools, etc., the substrate, and the in-stream fish cover. Depths of pools were also recorded in the field and then checked against the 1997 USCE 2-foot contours in the office. The widths were measured from the ArcView shapefile containing the mesohabitat line work.

Between Oroville and Yuba City there is a total of 61,333,019 ft^2 of habitat. The majority of the habitat is composed of glides (47%) and pools (36%). Riffles compose 7%, backwaters and runs compose 5% each, and boulder runs compose less than 1% of the total habitat. The data are shown on the Department's Arcview GIS coverage of the Project. The areas are shown in the table below. Figure 7 shows an example river atlas sheet developed from the ArcView coverage.

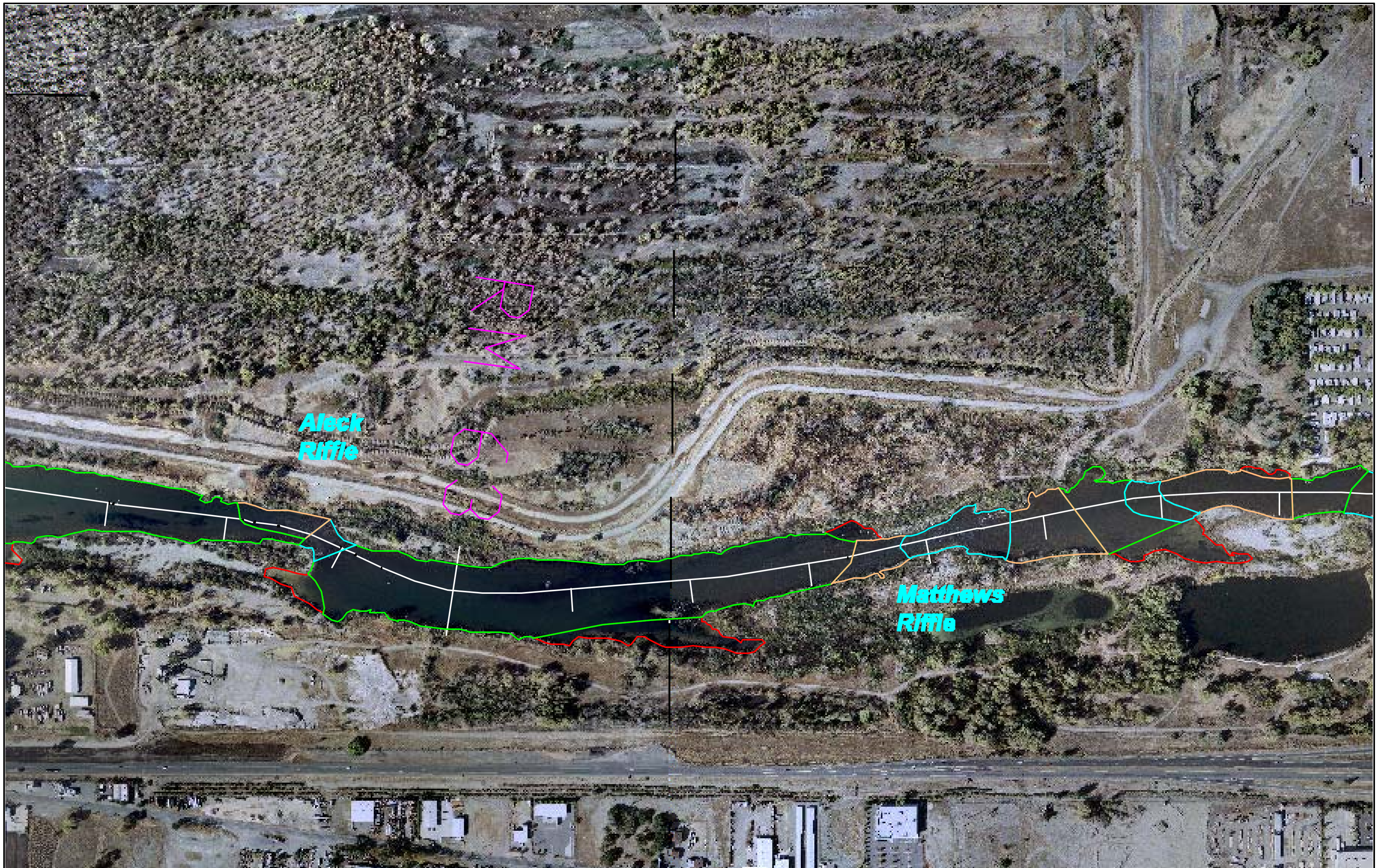
River miles 67 to 64 were designated as stream type "C" in the level one survey. The designations vary in the level two survey. From that point down to Yuba City the level

Table 15. Rosgen Level 1 Stream Typing

Cross-section (River Mile)	Bankfull Width (ft)	Bankfull Mean Depth (ft)	Width/Depth Ratio	Maximum Bankfull Depth (ft)	Flood Prone Area Width (ft)	Entrenchment Ratio	Water Surface Elev. (ft)	Valley Length	Sum of Channel Lengths	Channel Length	Sinuosity	Slope	Channel Pattern	Channel Material*	Shape	Stream Type	Date
67	326.3	21.0	15.54	40	465.9	1.4	142			5,279		0.0023			Shallow/Wide	C	Oct. 2002
66	172.9	3.0	57.63	6	402.1	2.3	130			4,752		0.0011			Shallow/Wide	C	Oct. 2002
65	207.8	2.5	83.14	5	258.2	1.2	125			2,110		0.0009			Shallow/Wide	C	Oct. 2002
64*	281.6	5.5	51.19	11	578.1	2.1	123	11944.2	17422	5,282	1.46	0.0009			Shallow/Wide	C	Oct. 2002
63	272.3	4.5	60.51	9	350.7	1.3	118			5,280		0.0000			Shallow/Wide	F	Oct. 2002
62	744.5	11.5	64.74	23	15557.4	20.9	118			5,278		0.0008			Shallow/Wide	F	Oct. 2002
61	275.5	1.0	275.48	2	291.6	1.1	114			5,279		0.0017			Shallow/Wide	F	Oct. 2002
60	312.4	2.0	156.20	4	361.2	1.2	105			5,279		0.0006			Shallow/Wide	F	Oct. 2002
59	446.8	3.0	148.94	6	477.0	1.1	102			5,280		0.0008			Shallow/Wide	F	Oct. 2002
58	157.4	1.5	104.95	3	173.3	1.1	98			5,280		0.0002			Shallow/Wide	F	Oct. 2002
57	361.6	4.0	90.39	8	898.1	2.5	97			5,277		0.0009			Shallow/Wide	F	Oct. 2002
56	645.4	2.7	239.05	7	703.6	1.1	92			5,279		0.0013			Shallow/Wide	F	Oct. 2002
55	429.7	1.0	429.66	2	477.1	1.1	85			5,281		0.0009			Shallow/Wide	F	Oct. 2002
54	329.6	3.5	94.17	7	379.1	1.1	80			5,280		0.0004			Shallow/Wide	F	Oct. 2002
53	439.1	6.0	73.19	12	740.4	1.7	78			5,278		0.0009			Shallow/Wide	F	Oct. 2002
52	252.6	4.0	63.15	8	741.0	2.9	73			5,280		0.0004			Shallow/Wide	F	Oct. 2002
51	499.6	7.0	71.37	14	694.4	1.4	71			5,279		0.0008			Shallow/Wide	F	Oct. 2002
50	363.9	6.0	60.66	12	521.2	1.4	67			5,279		0.0000			Shallow/Wide	F	Oct. 2002
49	219.0	4.5	48.67	9	1249.9	5.7	67			5,280		0.0004			Shallow/Wide	F	Oct. 2002
48	439.3	5.0	87.86	10	543.0	1.2	65			5,279		0.0009			Shallow/Wide	F	Oct. 2002
47	408.9	4.5	90.87	9	455.0	1.1	60			5,279		0.0006			Shallow/Wide	F	Oct. 2002
46	630.5	3.5	180.13	7	668.8	1.1	57			5,276		0.0006			Shallow/Wide	F	Oct. 2002
45	425.9	4.0	106.47	8	674.9	1.6	54			5,268		0.0006			Shallow/Wide	F	Oct. 2002
44	318.4	5.5	57.88	11	415.1	1.3	51			5,277		0.0002			Shallow/Wide	F	Oct. 2002
43	292.1	6.5	44.94	13	382.9	1.3	50			5,277		0.0004			Shallow/Wide	F	Oct. 2002
42	357.1	3.0	119.02	6	398.9	1.1	48			5,275		0.0002			Shallow/Wide	F	Oct. 2002
41	262.8	4.0	65.70	8	318.8	1.2	47			5,274		0.0002			Shallow/Wide	F	Oct. 2002
40	387.5	7.0	55.36	14	1435.3	3.7	46			5,278		0.0000			Shallow/Wide	F	Oct. 2002
39	208.0	4.5	46.22	9	235.4	1.1	46			5,278		0.0000			Shallow/Wide	F	Oct. 2002
38	246.4	2.5	98.56	5	269.2	1.1	46			5,274		0.0002			Shallow/Wide	F	Oct. 2002
37	340.0	8.5	40.00	17	4636.5	13.6	45			5,278		0.0011			Shallow/Wide	F	Oct. 2002
36	349.2	2.5	139.66	5	365.5	1.0	39			5,026		0.0002			Shallow/Wide	F	Oct. 2002
35	351.5	3.0	117.15	6	431.7	1.2	38			5,281		0.0006			Shallow/Wide	F	Oct. 2002
34	197.0	10.0	19.70	20	5498.4	27.9	35			5,277		0.0000			Shallow/Wide	F	Oct. 2002
33	236.7	4.0	59.18	8	269.2	1.1	35			5,278		0.0000			Shallow/Wide	F	Oct. 2002
32	224.0	10.5	21.33	21	301.3	1.3	35			5,278		0.0000			Shallow/Wide	F	Oct. 2002
31	277.9	7.5	37.05	15	2011.8	7.2	35			5,278		0.0004			Shallow/Wide	F	Oct. 2002
30	335.5	12.0	27.96	24	3378.6	10.1	33			5,278		0.0002			Shallow/Wide	F	Oct. 2002
29	281.9	4.5	62.65	9	311.6	1.1	32			5,279		0.0004			Shallow/Wide	F	Oct. 2002
28	231.0	6.0	38.50	12	205.2	0.9	30			5,280		0.0000			Shallow/Wide	F	Oct. 2002
27	711.9	2.0	355.95	4	746.8	1.0	30			3,192		0.0000			Shallow/Wide	F	Oct. 2002
27**	543.6	5.5	98.84	11	553.8	1.0	30			4,878		0.0000			Shallow/Wide	F	Oct. 2002
26	647.2	8.0	80.90	16	1765.5	2.7	30			5,310		0.0000			Shallow/Wide	F	Oct. 2002
25	319.7	6.5	49.18	13	384.3	1.2	30			6,434		0.0003			Shallow/Wide	F	Oct. 2002
24	290.6	4.5	64.57	9	332.2	1.1	28			5,450		0.0002			Shallow/Wide	F	Oct. 2002
23	327.8	2.5	131.12	5	341.6	1.0	27			5,209		0.0002			Shallow/Wide	F	Oct. 2002
22	476.7	5.0	95.34	10	526.8	1.1	26			5,144		0.0000			Shallow/Wide	F	Oct. 2002
21	589.0	6.5	90.61	13	829.0	1.4	26			5,412		0.0002			Shallow/Wide	F	Oct. 2002
20	567.7	3.5	162.19	7	606.9	1.1	25			5,472		0.0000			Shallow/Wide	F	Oct. 2002
19	554.8	5.0	110.96	10	608.1	1.1	25			5,321		0.0000			Shallow/Wide	F	Oct. 2002
18	480.2	5.5	87.31	11	1263.5	2.6	25			5,019		0.0002			Shallow/Wide	F	Oct. 2002
17	399.8	5.5	72.70	11	428.3	1.1	24			5,528		0.0000			Shallow/Wide	F	Oct. 2002
16	525.8	5.5	95.60	11	733.9	1.4	24			4,699		0.0002			Shallow/Wide	F	Oct. 2002
15	676.1	5.5	122.92	11	885.7	1.3	23	206824	261935	5,105	1.27	0.0000			Shallow/Wide	F	Oct. 2002
14	608.7	11.5	52.93	23	2677.4	4.4	23			4,474		0.0002			Shallow/Wide	C	Oct. 2002
13	718.0	6.5	110.45	13	2413.0	3.4	22			5,378		0.0000			Shallow/Wide	C	Oct. 2002
12	859.8	5.5	156.33	11	937.7	1.1	22			5,262		0.0004			Shallow/Wide	C	Oct. 2002
11	763.8	6.0	127.30	12	3988.9	5.2	20			4,434		0.0002			Shallow/Wide	C	Oct. 2002
10	778.5	6.5	119.76	13	2234.5	2.9	19			4,076		0.0002			Shallow/Wide	C	Oct. 2002
9	1167.1	10.8	108.06	24	no topos on west side	#VALUE!	18			5,321		0.0004			Shallow/Wide	C	Oct. 2002
8	623.6	6.5	95.94	13	706.2	1.1	16			5,509		0.0000			Shallow/Wide	C	Oct. 2002
7	414.6				6989.6	16.9	16			5,432		0.0000			Shallow/Wide	C	Oct. 2002
6	592.5				6608.5	11.2	16			5,355		0.0002			Shallow/Wide	C	Oct. 2002
5	482.9				6483.3	13.4	15			5,323		0.0000			Shallow/Wide	C	Oct. 2002
4	498.7				708.6	1.4	15			5,170		0.0002			Shallow/Wide	C	Oct. 2002
3	505.2				680.3	1.3	14			5,427		0.0000			Shallow/Wide	C	Oct. 2002
2	519.6				6771.4	13.0	14			5,050		0.0002			Shallow/Wide	C	Oct. 2002
1	452.7				6502.3	14.4	13			5,306		0.0002			Shallow/Wide	C	Oct. 2002
0	577.6				9556.2	16.5	12	68760.9	71515		1.04				Shallow/Wide	C	Oct. 2002

one designation was stream type “F”. Again, there were variations in designations based on the level two survey. These variations can be seen in the table below. Stream type “C” is described as “low gradient, meandering, point-bar, riffle/pool, alluvial channels with broad, well defined flood plains (Rosgen 1996).” Stream type “F” is described as “entrenched meandering riffle/pool channel on low gradients with high width/depth ratio” (Rosgen 1996).

Figure 12



SP-G2 FEATHER RIVER GEOMORPHIC STUDY

MESOHABITAT TYPING

LOWER FEATHER RIVER, ALECK AND MATHEWS RIFFLES

Backwater
Pool
Riffle
Glide

Oroville FERC Relicensing
(Project No. 2100)

5.1.5.2 Rosgen Level II Stream Typing

Table 16. Rosgen Level II River Classification from Oroville to Yuba City

USCE River Mile	DWR River Mile	Slope	Predominant Substrate	Stream Type
66.3-65.3	67-66	0.1052%	gravel	C4
65.3-64.4	66-65	0.0948%	gravel	C4c-
64.4-64	65-64.6	0.0947%	Cobble	C3c-
64-61	64.6-61.5	0.1705%	Cobble	F3
61-60	61.5-60.25	0.0568%	Boulder	F2
60-59	60.25-59.35	0.0758%	Gravel	F4
59-54	59.35-54.5	0.0379%	Cobble	F3
54-53	54.5-53.45	0.0947%	Gravel	F4
53-52	53.45-52.4	0.0379%	Cobble	F3
52-49	52.4-49.05	0.0379%	Gravel	F4
49-48	49.05-47.8	0.0947%	Cobble	F3
48-47	47.8-46.7	0.0568%	50% Gravel/ 50% Sand	F4/5
47-46	46.7-45.8	0.0569%	Cobble	F3
46-45	45.8-44.7	0.0569%	Sand	F5
45-37	44.7-36.75	0.1137%	Gravel	F4
37-27	36.75-27.5	0.0001%	Sand	F5

A Level II Rosgen stream classification survey was conducted from Oroville to Verona in the Fall of 2002. This was done using aerial photography and field checking of the substrate. The level one designation determines the type of stream and the level two makes further distinctions based on substrate and slope. The data are shown on the Department's Arcview GIS coverage of the Project and in Table 10. Figure 8 is an example river atlas sheet showing the stream classification.

5.1.5.3 Bank Protection and Levees

(In Progress)

6.0 SPAWNING RIFFLE MAPPING AND CHARACTERISTICS

6.1 METHODOLOGY AND RESULTS

The ___-mile reach of the Feather River between the Oroville Diversion Dam and the Honcut Creek tributary is one of the major salmon spawning habitats in Northern California. This stretch encompasses both the low- and high-flow reaches. The ____-mile low-flow reach from the Diversion Dam to the Thermalito Afterbay outflow contains ____ riffles. The____-mile low-flow reach from the Thermalito Afterbay outflow to Honcut Creek contains ____ riffles.

In coordination with fishery biologists, DWR will measure the actual spawning area in square feet of the riffles throughout the spawning reach. Representative areas at the head of riffles will be analyzed using bulk gravel sampling and surface sampling techniques to determine the surface and substrate quality of salmonid spawning gravel. Gradation curves for each riffle will be prepared and compared to similar investigations done in 1980, 1982, and 1997. Trend lines showing the changes in gravel size distribution will be prepared.

6.1.1 Spawning Riffle Mapping

6.1.1.1 Aerial Photo Atlas

"Prepare an aerial photo atlas using recent, rectified aerial photos. These will be used as a base layer for the GIS system. Map the spawning habitat on the atlas and the GIS."

This has been completed and is being used as a base amp for the Appendices.

6.1.1 Spawning Riffle Characteristics

“Plot redd counts and locations (information to be obtained from fisheries study results).”

(In Progress)

6.1.1.1 Physical Characteristics

“Identify, classify, and measure the velocity, width, depth, and length of spawning habitats.”

“In coordination with fishery biologists, DWR will measure the actual spawning area in square feet of the riffles throughout the spawning reach.”

(In Progress)

(In Progress)

Figure ____: Example of Aerial Photo Atlas

(In Progress)

Figure ____: Example of Plotted Redds (Arc-view coverage)

Table 17. Summary of 2002/2003 Spawning Riffle Characteristics, Lake Oroville to Yuba City

Riffle	River Mile (start)	River Mile (end)	Area (miles^2)	D50 Wolman Counts	D50 Bulk Analysis	Degree of Armoring
Hatchery Riffle						
Auditorium Riffle						
Bedrock Park Riffle						
Mathews Riffle						
Aleck Riffle						
Weir Riffle						
Great Western Riffle						
Robinson Riffle						
Steep Riffle						
Eye Riffle						
Gateway Riffle						
Sutter Butte Riffle						

Riffle	River Mile (start)	River Mile (end)	Area (miles^2)	D50 Wolman Counts	D50 Bulk Analysis	Degree of Armoring
Conveyor Belt Riffle						
Hour Riffle						
Keister Riffle						
Gridley Riffle						
McFarland Riffle						
Goose Riffle						
Herringer Riffle						

6.1.1.2 Sediment Characteristics

"Representative areas at the head of riffles will be analyzed using bulk gravel sampling and surface sampling techniques to determine the surface and substrate quality of salmonid spawning gravel."

"Prepare tables, charts, and figures showing riffle spawning area, gravel size distribution, and spawning gravel quality."

Spawning riffles were sampled between October 2002 and May 2003. Discharge on the Feather River during field sampling varied from the 600 cfs in the Low Flow Reach to 1,000 to 8,000 cfs in the High Flow Reach

DWR's 1982 river atlas showing previous sample sites was rectified so real world coordinates could be assigned to the sites. The 1996 sampling sites were transferred to an AutoCad base map so real world could be assigned to these. These locations were then located using the GPS along with 1982 River Atlas and the selecting the 2002-2003 sites were selected to duplicate the same geomorphic feature that previously been sampled. Sample sites were identified by historic riffle areas, originally selected based on historic spawning activity and previous sampling by the DWR, Northern District (1980).

Two riffles have been obliterated since 1982 due to the effects of high flows. The site of Great Western Riffle, previously at RM 62.7, is now a long pool. Sampling was done at the next downnriver riffle. Weir Riffle (RM 60.5) is now a glide

Table 18. Feather River Gravel Sampling Information

River Mile	Riffle	Year	Feature	Latitude	Longatude
67					
	Hatchery	1996	BS-1	39.3058539	-121.331591
	Hatchery	1982	BS-1	39.3059747	-121.331553
	Hatchery	1982	WS-102	39.3059177	-121.331526
	Hatchery	1982	WS-101	39.3059427	-121.331235
	Auditorium	1996	BS-2	39.3056782	-121.333323
	Auditorium	1982	BS-2	39.3057599	-121.333231
	Auditorium	1982	WS-2	39.3055974	-121.333234
	Auditorium	1982	WS-1	39.3057446	-121.333299
66					
	Bedrock Park	1982	BS-3	39.3046909	-121.340582
	Bedrock Park	1996	BS-3	39.3047898	-121.340248
	Bedrock Park	1982	WS-103	39.3048514	-121.340246
	Bedrock Park	1982	WS-4	39.3046952	-121.340683
	Bedrock Park	1982	WS-3	39.3043335	-121.341154
65					
	Mathews	1982	BS-4	39.2932441	-121.344494
	Mathews	1996	BS-4	39.2931917	-121.344555
	Mathews	1982	WS-19	39.2932879	-121.344377
	Mathews	1982	WS-20	39.2932442	-121.344389
	Mathews	1982	WS-21	39.293195	-121.344401
	Mathews	1982	WS-121	39.2938034	-121.344573
	Mathews	1982	WS-122	39.293729	-121.344598
64					
	Aleck	1996	BS-5	39.2900959	-121.344386
	Aleck	1982	BS-5	39.2856891	-121.34449
	Aleck	1982	WS-172	39.2856924	-121.344563
	Aleck	1982	WS-72	39.2855993	-121.344567
63					
	Great Western	1996	BS-6	39.282696	-121.345592
	Great Western	1982	BS-6	39.2826524	-121.345494
		1982	WS-173	39.2817011	-121.350274
		1982	WS-174	39.2816418	-121.350351
		1996	WS-?	39.2805647	-121.352554
		1982	WS-73	39.2810649	-121.352344
62					
	Robinson	1982	WS-74	39.2801773	-121.354369
	Robinson	1982	BS-7	39.2758887	-121.35477
	Robinson	1996	BS-7	39.2759557	-121.355244
	Robinson	1982	WS-175	39.2758328	-121.355926
		1982	WS-108	39.275497	-121.360361
		1982	WS-109	39.2753746	-121.360571

Table 18. Feather River Gravel Sampling Information

61	Riffle	Year	Feature	Latitude	Longatude
		1982	WS-110	39.2752151	-121.360873
		1982	WS-111	39.2750488	-121.361102
	Steep	1982	BS-8	39.2748849	-121.361123
	Steep	1996	BS-8	39.2748802	-121.36131
	Steep	1982	WS-107	39.2748172	-121.361185
		1982	WS-106	39.2745594	-121.361563
		1982	WS-105	39.2743043	-121.361452
		1982	WS-104	39.2744815	-121.361751
		1982	WS-5	39.2744037	-121.362021
	Weir	1982	WS-8	39.2742167	-121.362239
	Weir	1982	BS-9	39.2742332	-121.362342
		1996	BS-9	39.2742046	-121.362548
	Weir	1982	WS-7	39.2742004	-121.362418
	Weir	1982	WS-6	39.2741982	-121.362606
		1982	WS-9	39.2740103	-121.363229
		1982	WS-176	39.2730576	-121.364589
		1996	BS-New site	39.2726465	-121.364991
60					
	Gateway	1982	BS-10	39.2723687	-121.371898
	Gateway	1982	WS-112	39.2724405	-121.372038
	Gateway	1982	WS-113	39.2724979	-121.372173
	Gateway	1982	WS-10	39.2725498	-121.37229
	Gateway	1996	BS-10	39.2723924	-121.372053
		1982	WS-14	39.2720788	-121.374433
		1982	WS-15	39.2720547	-121.374668
		1982	WS-116	39.2722261	-121.37513
		1982	WS-117	39.2721955	-121.375223
		1982	WS-114	39.2719019	-121.380204
		1982	WS-115	39.2718995	-121.380724
59	XXXXXXXXXXXXXThermalito Afterbay SpillwayXXXXXXXXXXXXXXXX				
		1982	WS-11	39.271538	-121.380993
		1982	WS-12	39.2715174	-121.381138
		1982	WS-13	39.2714929	-121.381282
	Sutter Butte	1982	WS-118	39.2708406	-121.382209
	Sutter Butte	1982	WS-16	39.2707839	-121.382015
	Sutter Butte	1982	BS-11	39.2706088	-121.381725
	Sutter Butte	1982	WS-119	39.2705325	-121.381696
	Sutter Butte	1996	BS-11	39.2704928	-121.381694
	Sutter Butte	1982	WS-17	39.2704906	-121.381617
	Sutter Butte	1982	WS-120	39.2704439	-121.381431
	Sutter Butte	1982	WS-18	39.2703698	-121.381309
	Sutter Butte	1982	WS-127	39.2702438	-121.382159
	Sutter Butte	1982	WS-24	39.2701703	-121.381988
	Sutter Butte	1982	WS-126	39.2701749	-121.381891
	Sutter Butte	1982	WS-125	39.2702319	-121.381887
	Sutter Butte	1982	WS-124	39.2703326	-121.381883
	Sutter Butte	1982	WS-23	39.270379	-121.381789

Table 18. Feather River Gravel Sampling Information

58	Riffle	Year	Feature	Latitude	Longatude
	Big Hole	1982	WS-128	39.2618221	-121.381521
		1982	WS-25	39.2616998	-121.381514
		1982	WS-26	39.2615651	-121.381462
	Conveyor Belt	1982	WS-28	39.2605642	-121.38084
	Conveyor Belt	1982	WS-27	39.2605703	-121.381007
	Conveyor Belt	1982	WS-123	39.2604165	-121.380964
	Conveyor Belt	1982	BS-12	39.2603978	-121.381079
	Conveyor Belt	1996	BS-12	39.2603383	-121.381071
	Conveyor Belt	1982	WS-22	39.2603272	-121.380997
		1982	WS-29	39.2557051	-121.375646
		1982	WS-129	39.2554149	-121.3757
57					
		1982	WS-130	39.2550129	-121.37454
		1982	WS-30	39.2547998	-121.374694
		1982	WS-131	39.2547055	-121.373819
		1982	WS-132	39.2546632	-121.373806
		1982	WS-133	39.2546139	-121.373804
		1982	WS-31	39.2545263	-121.373688
		1982	WS-32	39.2544711	-121.373646
		1982	WS-134	39.2538707	-121.372841
	Hour	1982	WS-33	39.2537144	-121.372764
	Hour	1982	BS-13	39.2535831	-121.372916
	Hour	1996	BS-13	39.253443	-121.372858
		1982	WS-34	39.253381	-121.372818
		1982	WS-35	39.2522958	-121.372799
		1982	WS-135	39.2508948	-121.37308
		1982	WS-36	39.2508457	-121.372978
		1982	WS-37	39.2505969	-121.373212
56					
		1982	WS-136	39.2504392	-121.373439
	Keister	1982	WS-38	39.2432008	-121.371323
	Keister	1982	WS-39	39.2430868	-121.371061
55					
	Keister	1996	BS-14	39.2428422	-121.370595
	Keister	1982	BS-14	39.2427923	-121.370525
	Keister	1982	WS-139	39.2428091	-121.370142
	Keister	1982	WS-138	39.2427046	-121.370311
	Keister	1982	WS-137	39.242663	-121.370531
	Keister	1982	WS-40	39.2425618	-121.370503
	Keister	1982	WS-41	39.2424752	-121.370449
	Goose	1996	BS-15	39.242089	-121.370136
	Goose	1982	BS-15	39.2419465	-121.37023
	Goose	1982	WS-140	39.2416237	-121.370224
	Goose	1982	WS-141	39.2413184	-121.37051

Table 18. Feather River Gravel Sampling Information

54	Riffle	Year	Feature	Latitude	Longatude
	Big	1996	BS-17	39.2341549	-121.371849
	Big	1982	WS-142	39.2340387	-121.372147
	Big	1982	BS-17	39.2339022	-121.372092
	Big	1982	BS-16	39.2338542	-121.372167
	Big	1982	WS-143	39.2338091	-121.372172
		1982	WS-43A	39.2338143	-121.371976
		1982	WS-43B	39.2311699	-121.373902
		1982	WS-144	39.2311226	-121.374012
		1982	WS-44	39.2307869	-121.374202
53					
	MacFarland	1982	WS-145	39.2243242	-121.375469
	MacFarland	1982	WS-146	39.224277	-121.375524
	MacFarland	1982	WS-45	39.2242121	-121.375541
	MacFarland	1982	WS-46	39.2241448	-121.375494
	MacFarland	1982	WS-47	39.2241117	-121.375387
	MacFarland	1982	WS-147	39.2239827	-121.375451
	MacFarland	1982	WS-148	39.2239525	-121.375359
	MacFarland	1982	BS-18	39.2239126	-121.375547
	MacFarland	1996	BS-18	39.2231559	-121.375663
	MacFarland	1982	WS-149	39.2230366	2262827.186
	MacFarland	1982	WS-150	39.2229829	-121.37563
	MacFarland	1982	WS-48	39.2228432	2262630.204
52, 51,50					
	Gridley	1982	WS-50	39.2120243	-121.375897
	Gridley	1982	WS-49	39.212028	-121.375815
	Gridley	1982	WS-151	39.2116843	-121.37551
	Gridley	1996	BS-19	39.2115881	-121.375224
	Gridley	1982	BS-19	39.2115341	-121.37526
	Gridley	1982	WS-51R	39.2114257	-121.375261
	Gridley	1982	WS-51L	39.2115299	-121.375049
	Gridley	1982	WS-152	39.2117298	-121.374751
	Gridley	1982	WS-162	39.2119556	-121.374628
	Gridley	1982	WS-55	39.2120759	-121.374584
	Gridley	1982	WS-53	39.2117487	-121.374524
	Gridley	1982	WS-54	39.2118521	-121.374504
	Gridley	1982	WS-154	39.2117748	-121.37443
	Gridley	1982	WS-156	39.2110033	-121.373579
	Gridley	1982	WS-157	39.2111895	-121.373598
	Gridley	1982	WS-56	39.2111334	-121.373325

Table 18. Feather River Gravel Sampling Information

49	Riffle	Year	Feature	Latitude	Longatude
		1996	BS-20	39.2048843	-121.373497
		1982	WS-57	39.2049256	-121.373672
		1982	WS-58R	39.2049009	-121.373945
		1982	WS-58L	39.2048207	-121.37376
		1982	WS-159	39.2048103	-121.374061
		1982	WS-59	39.2047474	-121.373894
		1982	WS-60	39.2046406	-121.373876
		1982	WS-160	39.2045648	-121.374138
		1982	WS-62B	39.2040215	-121.373841
		1982	WS-161	39.2032764	-121.373933
		1982	WS-62A	39.2032706	-121.374206
		1982	WS-61	39.2031702	-121.374026
		1982	WS-164	39.2017414	-121.37494
		1982	WS-163	39.2016938	-121.375153
		1982	WS-63	39.2015975	-121.374942
		1982	WS-64	39.2014075	-121.375023
48					
		1982	WS-65	50.1134976	-140.102905
		1982	WS-66	39.194518	-121.374681
47					
	Herringer	1982	WS-165	39.1945074	-121.371373
	Herringer	1982	WS-166	39.1911452	-121.371608
	Herringer	1982	WS-161	39.1910292	-121.371266
	Herringer	1982	WS-68	39.1901425	-121.371654
	Herringer	1982	WS-167	39.190096	-121.372363
	Herringer	1982	WS-69	39.1900485	-121.372535
46					
		1982	WS-168	39.1818154	-121.374296
		1982	WS-169	39.1802255	-121.37531
		1982	WS-170	39.1800313	-121.375249
		1982	WS-70	39.175935	-121.375115
		1982	WS-171	39.1757365	-121.375042
45					
		1982	WS-71	39.1745326	-121.37313

6.1.1.2.1 Bulk Sampling

"Sample and sieve gravel from the upstream end of salmonid spawning habitats."

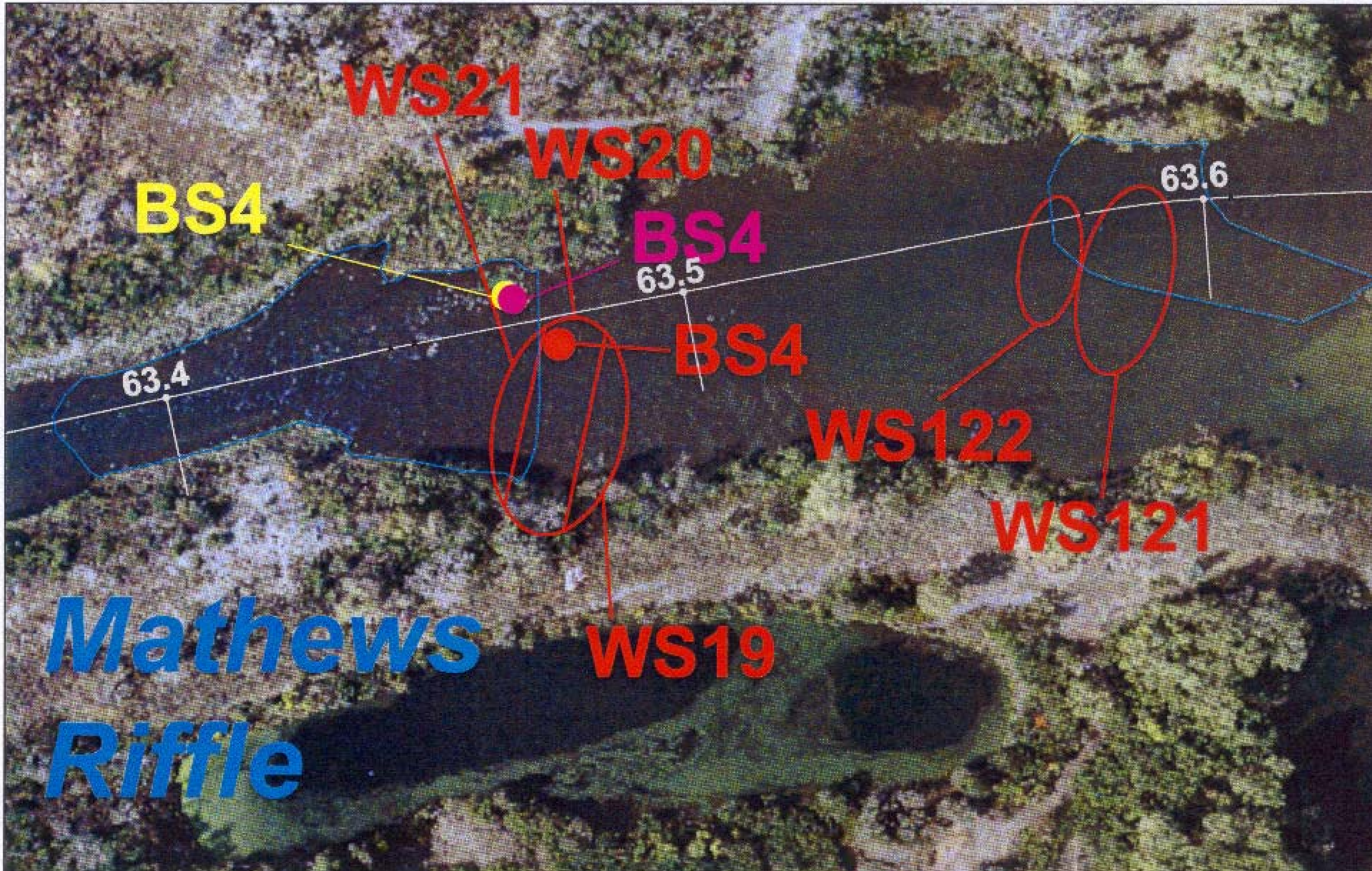
Bulk Sampling

Bulk sampling is the collecting and sieving of stream gravel. Four commonly used methods are:

1) Freeze core method;
2) Excavated core (McNeil Sampling);
3) Sampling by shovel
4) Sampling by shovel with a stilling well
4) Scoops and clamshells

The freeze core method is slow and expensive and does not produce a large enough sample in coarse gravel substrates to be statistically representative.

McNeil sampling is effective in fine gravel substrate, but the core barrel is difficult to drive into coarse gravel and cobbly gravel found in the study area.



SP-G2 GEOMORPHIC STUDY
Lower Feather River, Mathews Riffle
Wolman and Bulk Sample Sites 1982, 1996, 2002

1982 Sample Sites
1996 Sample Sites
2002 Sample Sites

100 0 300
Feet

Clamshells and scoops are generally designed for use in sand or finer sediments and take samples limited to a few pounds. In coarser sediment, the fines generally wash out before the sample is retrieved.

Grost et al (1991) compared the freeze core, excavated core and shovel methods for sample composition, cost and field efficiency. The methods were field-tested on substrate consisting primarily of materials smaller than 10 cm (4 inches) in diameter. Water depths ranged from 6 to 40 centimeters (2.4 to 16 inches), and mean water velocities ranged from 20 to 80 centimeters per second (0.6 to 2.6 feet per second). Test results indicated no significant differences between the excavated core and shovel samples for any size-fraction of particles.

Grost et al concluded that a shovel is a viable alternative to an excavated core sampler for sampling in streams less than 1.3 feet deep with water velocities less than 2.6 feet per second and a stream bed consisting primarily of material smaller than 4 inches in diameter. They considered shovel sampling especially attractive for sampling in remote areas, in coarse substrates, or when sampling budgets are limited.

A stilling well used with standard shovel was concluded by Hames et al to be an adequate substitute to the McNeil Sampler and that there were no statistical differences between the methods in mean percent fine sediment or geometric fine particle size between the two methods. There were significant statistical differences in these categories using the standard shovel method. The percentage of fines was biased (low) in comparison to the McNeil samples and due to the large amount of variation; regressions were not useful in converting to equivalent McNeil Sampler measurements.

The samples collected in 1982 used a 14” McNeil styled sampler; in 1996, the shovel method was used and in 2002-2003 the shovel method along with stilling well was used. The stilling well was made from a 30” diameter, 2’ high corrugated pipe. The shovel with stilling well method was used due to the ease to collect a large clast size samples that statistically comparable to the McNeil sampler as used in 1982.

Sample Quantity

Sample standards have been established by many organizations for numerous purposes. Most are inconsistent, established for different sizes, or for different purposes

Criteria established by Church et al (1987) used to determine sample size in kilograms (2.204 pounds equal one kilogram) are shown in Figure 6. It shows the variation in required sample quantity as controlled by the b-axis length of the largest particle and the percentage of the sample that this size represents. The ISO low precision standard is shown in the far left. It is based on the sampling of sand and fine gravel with resultant reasonable sample sizes. However, for samples with largest stones in the range of 7 to 9 inches that are typical of the coarsest riffles on the Feather River, sample sizes would range from 2000 to 3500 pounds.

Church et al (1987) recommends the use of the 0.1 percent line to maximum particle size up to 32 millimeters (1.3 inches), the 1 percent line to 128 millimeters (5 inches) and the 5 percent line for samples with larger clasts. The latter results in a sample size of about 700 pounds for a 9-inch particle.

Church et al (1987) also state that in fishery studies where the proportion of fines are used to measure suitability, the samples may be truncated by not considering particles larger than 64 millimeters (2.5 inches). This can be done since the few larger particles will not influence the habitat issue materially. This imposes a sample size requirement of 80 pounds to meet the one percent and about 770 pounds to meet the 0.1 percent criteria in Figure 6.

These criteria are informal and no statistical assumptions are made. Sampling precision for the larger particles is low, probably in the plus or minus 5 percent range, but high enough to make spawning gravel quality determinations. Meeting ISO or higher precision standards for the 6- to 9-inch diameter fraction would require heavy equipment and production sieves.

The sample area surface dimension was 5-6 foot circle. The surface layer was collected and sieved separately from the subsurface layer. The surface layer sampling depth is defined by the diameter of the largest particle, generally ranging from four to seven inches. The maximum sampling depth of the subsurface layer was determined by the required sampling weight and typically extended to a depth of 12 to 16 inches by 30 inches in diameter.

In 2002-2003, at Riffles that had distinctive dune and trough sequences two bulk samples were taken, one for each feature. The same size of surface sample was collected at each feature, but only half the subsurface was collected witch was later statistically treated as one sample.

Sieving

Determining particle size distribution and spawning gravel quality generally begins with sieve analysis. The sieving determines the grading of gravel, which is the distribution of particles into standard size groups based on sieve mesh openings. Dimensions are recorded in mesh size units for smaller fractions and English units for coarser fractions (see unit conversion on inside of rear cover).

Conforming to the Unified Soil Classification System (USCS), fines pass a number 200 mesh sieve (0.074 mm). Coarse grains are larger than a number 200. Coarse grains are divided into, in ascending order, sand, gravel, and cobbles. Cobbles range from 3 inches to 10 inches in diameter. Gravel ranges from a number 4 sieve (4.75 mm) to 3 inches. The USCS defines sand as smaller than a number 4 sieve and larger than a number 200 sieve (0.074 mm).

Fines are of three types: silt, clay, and organic soils. Size distinction is not made between silt and clay in the USCS but are differentiated by low (silt) or high (clay) plasticity.

The sieving splits the sample into size fractions which are tabulated or plotted as histograms or gradation curves. Table____lists the sieve sizes used.

The field sieve dimensions are two feet square with openings ranging from 3 inch to #4 mesh. Particles between 3 and 6 inches and particles larger than 6 inches were separated by hand using a ruler and weighed separately. The size and weight of all the cobbles greater than 6 inches were recorded with the largest particle used to estimate the required sample size. The field sieves were placed above a large plastic catchment to collect and settle material smaller than the #4 sieve for laboratory analysis. A five-gallon bucket was used to carry water for washing the material through the sieves. Material retained on each sieve was weighed in a bucket on a hanging scale with the weight being recorded to the closest 1/8 pound.

Particles passing through the #4 mesh sieve was bagged and subsequently air dried at the office. After drying the sample was weighed and split by quartering method to obtain a representative sample in the 6 to 12 pound range for laboratory sieving.

Laboratory sieves ranged from #4 mesh to #200 mesh. The representative sample was then sieved with a mechanical shaker in 1 to 2 pound runs for 15 minutes each. The sample weight was adjusted to represent the full sample weight. Material retained on each sieve was weighed on a balance to the nearest 0.01 lbs.

Table 19. Sieve Sizes used in 1982, 1996, 2003 Bulk Sampling

(In Progress)

Table 19. Gravel Sampling Sieve Sizes

1982 Sieve Sizes	1996 & 2002/2003 Sieve Sizes
	6"
3"	3"
	1.5"
1"	
	0.75"
0.5"	
	0.375"
	#4 (0.187")
0.16"	
	#8 (0.0937")
	#16 (0.0469")
	#30 (0.0234")
0.015"	
	#50 (0.0117")
	#100 (0.0059")
	#200 (0.0029")

Bulk Sampling Data Analysis

Mechanical analysis results are plotted on semi-logarithmic graphs, and are referred to as gradation curves or mechanical analysis graphs, such as shown in Figure 8. Gradation curves graphically present the percentage of particles retained and passing through specific sieve apertures. Appendix A contains gradation curves for all sampled riffles.

The bulk samples were analyzed in three categories: surface, subsurface, and combined surface and subsurface. Twenty bulk samples were taken from the Hatchery Riffle at River Mile 66.0 to Junkyard Riffle at River Mile 48.7.

The plot of the combined curve is the most important indicator of suitability because it represents the entire composition of the gravel used by the salmon.

The plot of the surface sample is important in coarse substrates because it provides an indicator of armoring and the ability of the salmon to excavate the river bed.

A measure of armoring degree may be determined by comparing the surface and subsurface samples.

Along the X-axis, mesh numbers and sieve aperture sizes are arranged logarithmically. The sieve numbers refer to the nominal number of openings per inch: a #4 mesh sieve means that there are 4 openings per inch and an aperture dimension of 4.76 millimeters or 0.187 inches, a #200 mesh sieve has 200 openings per inch and an aperture dimension of 0.0029 inches.

The arithmetic Y-axis is divided into percent coarser by weight on the right side of the graph and percent finer by weight on the left side.

Table 20. Bulk Sample Data Sheet

FEATHER RIVER SPAWNING GRAVEL ANALYSIS

FIELD ASSESSMENT

Date : 12/18/2002 Time: 12:25-16:50 Project: FERC (Feather R. DS) Sample #: BS-4

By: Glen Gordon; Clint Andreasen Site Location: Mathews Riffle

Sift # / Sample #	Sift 1 lbs w/bucket	Sift 1 lbs -bucket	Sift 2 lbs w/bucket	Sift 2 lbs -bucket	Sift 3 lbs w/bucket	Sift 3 lbs -bucket	Sift 4 lbs w/bucket	Sift 4 lbs -bucket	Sift 5 lbs w/bucket	Sift 5 lbs -bucket	TOTAL WEIGHT	% of Sample	% Passing	% Retained
"Max int dia "	7.25"													
> 6"	*Note: Enter all >6" on page 2*										56.000	9.525	90.475	9.525
3 - 6"	61.000	58.875	38.000	35.875	8.625	6.500		0.000		0.000				
3 - 6"		0.000		0.000	50.375	48.250		0.000		0.000	149.500	25.428	65.047	34.953
1 1/2 - 3"	17.500	15.375	35.375	33.250	39.625	37.500		0.000		0.000				
1 1/2 - 3"		0.000		0.000		0.000		0.000		0.000	86.125	14.649	50.398	49.602
3/4 - 1 1/2"	24.875	22.750	30.875	28.750	36.250	34.125		0.000		0.000	85.625	14.564	35.834	64.166
3/8 -3/4"	20.250	18.125	23.750	21.625	33.250	31.125		0.000		0.000	70.875	12.055	23.779	76.221
#4 - 3/8"	15.250	13.125	17.750	15.625	25.250	23.125		0.000		0.000	52.118	8.865	14.914	85.086
Totals		128.250		135.125		180.625		0.000		0.000	500.243	85.086		

Bucket Weight= 2.125

Total Weight < #4 (dry):=====> 87.930 Date 2/26/2003

Comments:

LABORATORY ASSESSMENT

Date: Feb. 26, 2003 Person sieving: Eamonn Foster

ROTOTAP: yes / no Sieving duration (per run) 15 (min)

Sieve Size	WT Tare	Sift 1 lbs w/tare	Sift 1 lbs -tare	Sift 2 lbs w/tare	Sift 2 lbs -tare	Sift 3 lbs w/tare	Sift 3 lbs -tare	Sift 4 lbs w/tare	Sift 4 lbs -tare	Sift 5 lbs w/tare	Sift 5 lbs -tare	Sift 6 lbs w/tare	Sift 6 lbs -tare	Sift 7 lbs w/tare	Sift 7 lbs -tare
> # 4	1.140	1.15	0.010	1.145	0.005	1.1401	0.000	1.1401	0.000	1.1401	0.000	1.15	0.005	1.15	0.010
# 8 - # 4	1.085	1.63	0.545	1.65	0.565	1.48	0.395	1.68	0.595	1.49	0.405	1.48	0.395	1.48	0.395
# 16 - # 8	0.965	1.37	0.405	1.33	0.365	1.3	0.335	1.35	0.385	1.26	0.295	1.27	0.305	1.34	0.375
# 30 - # 16	1.020	1.225	0.205	1.19	0.170	1.245	0.225	1.22	0.200	1.195	0.175	1.25	0.230	1.34	0.320
# 50 - # 30	0.820	0.88	0.060	0.86	0.040	0.895	0.075	0.87	0.050	0.87	0.050	0.91	0.090	0.97	0.150
# 100 - # 50	0.795	0.8	0.005	0.7951	0.000	0.8	0.005	0.8	0.005	0.8	0.005	0.81	0.015	0.84	0.045
# 200 - # 100	0.905	0.9051	0.000	0.9051	0.000	0.9051	0.000	0.9051	0.000	0.9051	0.000	0.91	0.005	0.92	0.015
< # 200	0.950	0.9501	0.000	0.955	0.005	0.9501	0.000	0.955	0.005	0.955	0.005	0.96	0.005	0.96	0.010
Totals	7.68		1.230		1.150		1.035		1.240		0.935		1.050		1.320

Sieve Size	WT Tare	Sift 8 lbs w/tare	Sift 8 lbs -tare	Sift 9 lbs w/tare	Sift 9 lbs -tare	Sift 10 lbs w/tare	Sift 10 lbs -tare	Total	% of fines	% of total sample	% Passing	% Retained
> # 4	1.140	1.14	0.000	1.14	0.000		0.000	0.030	0.2766			
# 8 - # 4	1.085	1.49	0.400	1.43	0.345		0.000	4.040	36.757	5.4973	9.417	90.583
# 16 - # 8	0.965	1.35	0.380	1.44	0.475		0.000	3.320	30.206	4.5176	4.900	95.100
# 30 - # 16	1.020	1.35	0.330	1.42	0.395		0.000	2.250	20.471	3.0616	1.838	98.162
# 50 - # 30	0.820	1.01	0.185	1.04	0.220		0.000	0.920	8.3703	1.2519	0.586	99.414
# 100 - # 50	0.795	0.88	0.085	0.89	0.095		0.000	0.260	2.3664	0.3539	0.232	99.768
# 200 - # 100	0.905	0.93	0.025	0.95	0.045		0.000	0.090	0.8234	0.1231	0.109	99.891
< # 200	0.950	0.97	0.020	0.98	0.030		0.000	0.080	0.7297	0.1091	0.000	100.000
Totals	7.68		1.425		1.605		0.000	10.991	100	14.914		

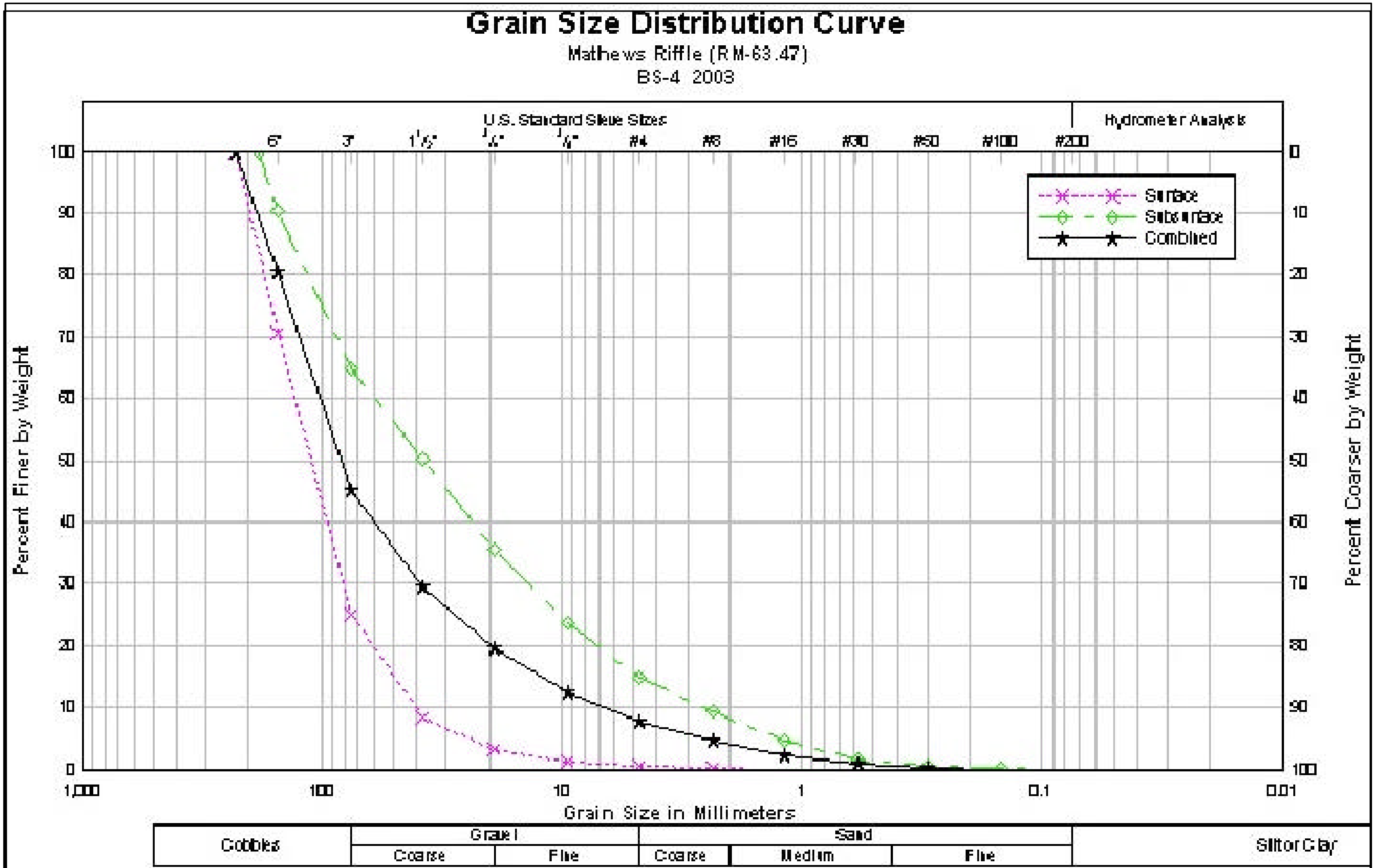
Oversize weight (>#4) 0.243

Comments: Rep Sample weight=11.00 lbs

Table 21. Bulk Sample Statistics

Sample	River Mile	plus/minus	Distance	Actual RM	D95	D84	D50	Dg	D16	D5	phi(g)	skewness	kurtosis
BS-01A	66.0	plus	275.6096	66.05	47.0	36.0	14.0	7.5	1.6	1.0	4.77	-0.3	0.23
BS-01B					35.0	22.0	6.0	5.8	1.5	0.9	3.81	-0.03	0.36
BS-02A	66.8	minus	102.7385	66.78	38.0	27.0	10.0	6.6	1.6	0.9	4.12	-0.3	0.32
BS-02B					47.0	37.0	8.0	6.8	1.3	0.6	5.44	-0.09	0.28
BS-03A	66.2	plus	217.4847	66.24	129.0	112.0	96.0	93.5	78.0	52.0	1.2	-0.15	1.51
BS-03B					137.0	112.0	88.0	41.7	15.5	2.3	2.69	-0.76	1.07
BS-04A	63.5	minus	130.8481	63.48	58.0	52.0	45.0	42.1	34.0	22.0	1.24	-0.32	1.28
BS-04B					52.0	44.0	29.0	23.5	12.5	5.4	1.88	-0.34	0.8
BS-05A	62.8	minus	102.7364	62.78	123.0	98.0	78.0	51.4	27.0	5.9	1.9	-0.64	1.36
BS-05B					46.0	36.0	9.4	7.4	1.5	0.8	4.9	-0.15	0.27
BS-06A	62.2	minus	116.8276	62.18	225.0	138.0	108.0	108.9	86.0	64.0	1.27	0.04	1.66
BS-06B					80.0	72.0	38.0	26.0	9.4	1.8	2.77	-0.37	0.86
BS-07A	61.2	minus	55.5007	61.19	88.0	78.0	19.0	13.4	2.3	0.7	5.82	-0.2	0.37
BS-07B					88.0	76.0	25.0	11.7	1.8	1.6	6.5	-0.41	0.07
BS-08A	60.7	plus	63.3522	60.71	78.0	58.0	25.0	15.6	4.2	0.5	3.72	-0.36	0.89
BS-08B					94.0	82.0	30.0	22.6	6.2	0.7	3.64	-0.22	0.91
BS-09A	60.5	minus	58.5414	60.49	78.0	76.0	70.0	52.3	36.0	18.0	1.45	-0.78	0.96
BS-09B					78.0	76.0	44.0	26.4	9.2	0.8	2.87	-0.48	1.16
BS-10A	59.5	plus	129.9441	59.52	96.0	88.0	78.0	67.7	52.0	37.0	1.3	-0.54	0.81
BS-10B					78.0	59.0	37.0	33.5	19.0	7.0	1.76	-0.18	1.13
BS-11A	58.4	plus	64.4726	58.41	56.0	49.0	30.0	35.0	25.0	17.0	1.4	0.46	0.77
BS-11B					54.0	46.0	21.0	22.0	10.5	0.7	2.09	0.06	1.9
BS-12A	57.2	minus	147.3785	57.17	80.0	74.0	52.0	28.5	11.0	4.0	2.59	-0.63	0.57
BS-12B					68.0	48.0	17.0	13.9	4.0	1.2	3.46	-0.16	0.62
BS-13A	56.3	plus	315.6384	56.36	90.0	84.0	64.0	38.9	18.0	3.0	2.16	-0.65	1.21
BS-13B					82.0	64.0	23.0	13.9	3.0	0.7	4.62	-0.33	0.54
BS-14A					58.0	50.0	44.0	32.4	21.0	14.0	1.54	-0.7	0.64
BS-14B					82.0	72.0	27.0	20.8	6.0	2.4	3.46	-0.21	0.42
BS-15A					76.0	74.0	44.0	29.2	11.5	2.2	2.54	-0.44	0.9
BS-15B					80.0	56.0	19.0	13.4	3.2	0.8	4.18	-0.24	0.61
BS-16A					78.0	66.0	40.0	24.6	9.2	0.8	2.68	-0.49	1.31
BS-16B					84.0	72.0	23.0	14.5	2.9	0.6	4.98	-0.29	0.54
BS-17A					84.0	60.0	15.0	9.8	1.6	0.5	6.12	-0.23	0.41
BS-17B					90.0	86.0	80.0	35.9	15.0	3.1	2.4	-0.92	0.93
BS-18A					88.0	80.0	50.0	35.8	16.0	3.5	2.24	-0.42	1
BS-18B					112.0	96.0	38.0	26.5	7.3	3.3	3.62	-0.28	0.37
BS-19A					78.0	46.0	18.0	9.1	1.8	0.6	5.05	-0.42	0.48
BS-19B					55.0	46.0	38.0	20.4	9.0	1.3	2.26	-0.76	1.29

FIGURE 14



BULK SAMPLING GRAIN SIZE DISTRIBUTION CURVE

Lower Feather River, Mathews Riffle

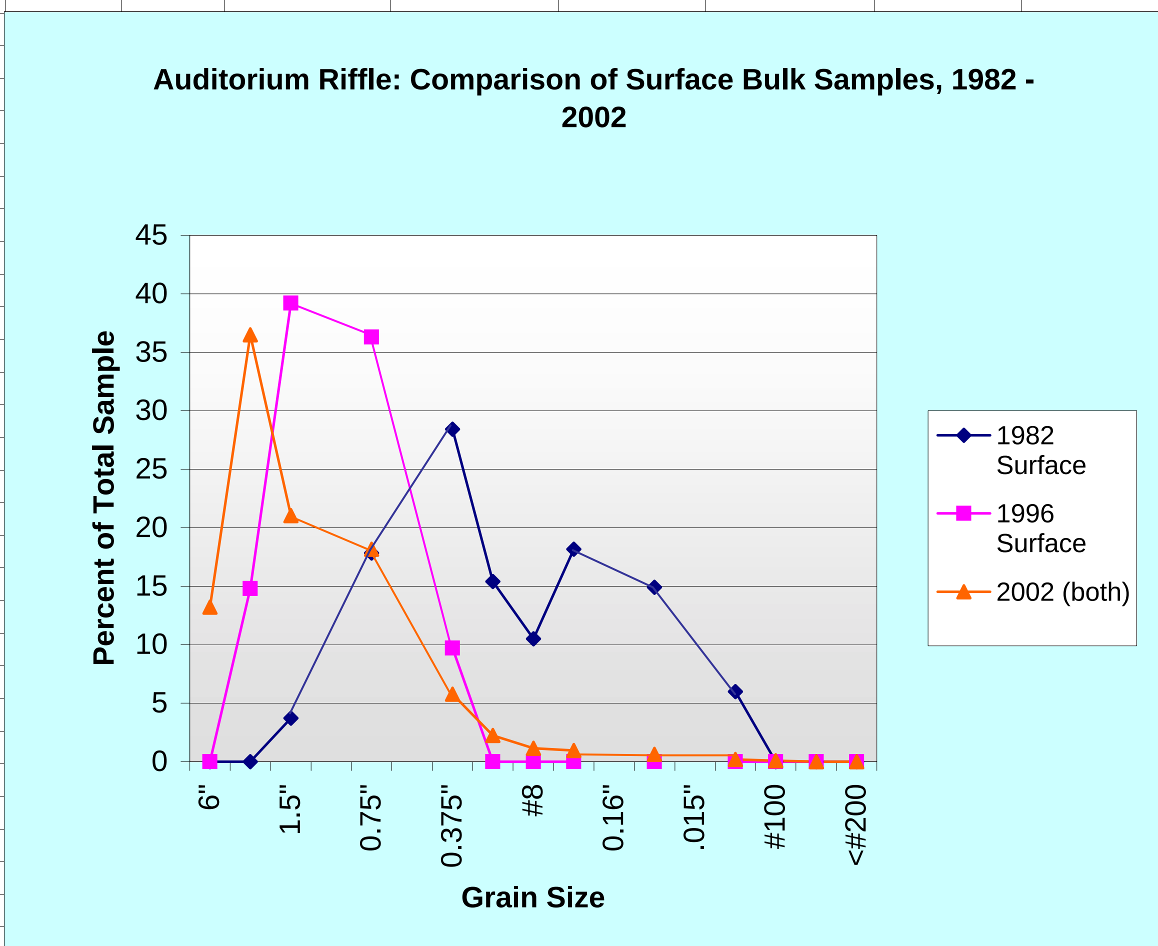
Filename:N:\RAID1\Geo\PROJECTs\Feather River\0 - Interim Report\Figures\Latest Numbered Figures\Figure 14 - Bulk Sampling Grain Size Distribution Curve (example) 5-8-03.dwg
Layout Name:Layout3-Layout1 Plot Time: May 19, 2003 - 3:58pm

Oroville FERC Relicensing
(Project No. 2100)

Figure 15. Bulk Sample Trends, Lower Feather River

January 31, 2003: Auditorium Riffle, Comparison of Bulk Samples, 1982 - 2002

GRAIN SIZE	GRAIN SIZE	1982 BS-2 Surface Sample (original)	1982 BS-2 Surface Sample (interpolated)	1996 BS-2 Surface Sample	2002 BS-2 Surface Sample (A and B)	2002 BS-2A Surface Sample	2002 BS-2B Surface Sample
(INCHES)	(MM)		1982 Surface	1996 Surface	2002 (both)	2002 Surface A	2002 Surface B
6"	152.4	0.00	0.00	0.00	13.2	0.00	26.41
3"	76.2	0.00	0.00	14.80	36.5	35.54	37.45
1.5"	38.1		3.72	39.20	21.0	25.09	16.99
1"	25.4	5.90					
0.75"	19.05		17.82	36.30	18.2	23.17	13.17
0.5"	12.7	37.70					
0.375"	9.53		28.42	9.70	5.8	7.65	3.92
#4	4.75		15.39	0.00	2.2	3.39	1.11
#8	2.38		10.50	0.00	1.2	1.94	0.39
#16	1.18		18.16	0.00	1.0	1.64	0.28
0.16"	4.00	25.20					
#30	0.60		14.90	0.00	0.6	1.09	0.16
.015"	0.40	31.20					
#50	0.30		5.99	0.00	0.2	0.29	0.09
#100	0.15		0.00	0.00	0.1	0.18	0.01
#200	0.07		0.00	0.00	0.0	0.00	0.00
<#200			0.00	0.00	0.00	0.00	0.00
			114.90	100.00	100.0	99.98	99.97



6.1.1.2.2 Surface Sampling

"Conduct Wolman surface grid sampling at representative sieve sites."

Sampling was done as close to the 1982 and 1996 sites as possible.

Sampling sites, except for a few exceptions, were located at the head of point bars. The head, or upstream end of a point bar, was selected as the sampling site for several reasons. First, the same geomorphic area within the river was consistently sampled so that downstream trends in grain size would be apparent. Second, the most ideal hydrologic conditions for spawning, and therefore most of the spawning, generally occur at the head of riffles. Most riffles are in the river adjacent to the head of the point bar. Third, the gravel size distribution on the riffle is similar to the point bar because both were deposited under the same hydraulic conditions during floods.

Deposits finer than what were sampled occur farther downstream on the point bar and in other places, but these deposits generally occur in areas with poor spawning conditions.

Two types of sampling methodology were used: bulk sampling and surface or Wolman sampling.

A gradation curve shows the grading characteristics of a sample. A very steep curve, with no tail, indicates a poorly graded, relatively uniform sample with a small range of particle sizes. Conversely, a gentle curve indicates a well graded sample with a wide range of particle sizes. An example of the surface, subsurface, and combined curves are plotted in Figure ___.

Figure 8 shows the difference between the surface and subsurface D50 and Dg values at each riffle site for 1982 and 1995. The armoring effect on many of the Low Flow Reach riffles is easily recognizable when surface and subsurface values are compared; surface diameters and, subsequently, D values are twice or more the size of subsurface diameters. A coarsening in the subsurface can also be seen developing at some sites. The subsurface Dg values show that there is generally less skewness below the surface layer.

Table III is a listing of bulk sample statistics, including aspects of central tendency such as geometric mean diameter (Dg), standard deviation, D95, D84, D75, D50, D25, D16, D5, skewness and kurtosis.

These dimensions are based on standard deviation increments: the D84 and D16 dimensions fall one standard deviation on either side of the median (D50) and the D95 and D5 dimensions fall two standard deviations on either side of the median.

The statistical parameters for sample BS-2 show the effect of imported gravel on the analysis for that site. Sampling was done at the toe of Moe's Ditch where imported gravel was deposited after being scoured from the upper ditch area. This redistribution of gravel shows that material will move down through the river system and provide beneficial use as it travels.

Surface Sampling

Surface samples were taken at the 20 riffles using a modified Wolman (1954) grid method. The area sampled included or was immediately adjacent to the bulk sample site.

The Wolman method, with minor variations, was selected because of its relative simplicity and common usage. This method requires that individual stones be measured on the intermediate or b-axis by ruler or calipers, or classified using square openings in a template. In 2002 to 2003 a ruler was used.

The distance between successively sampled particles is significant because of the propensity for particles of similar size to imbricate. The sample grid is chosen, usually on a 2.5 or 5 foot spacing, so that successively selected particles are at least several grain diameters apart. This is done by laying out 2 or 3 tapes to keep the sampling evenly spaced and taking a step or steps between each sample point. After each pace(s), the eyes are closed; the first particle touched with a pointer is picked up. The particle's b-axis is measured and recorded. This is continued until 100+ samples are recorded. The grid is tied into world coordinates by using the GPS to record a point within the grid.

The b-axis measurement is taken with a ruler scaled in millimeters and then later converted to phi units, with phi = -log2 of the b-axis diameter in millimeters. The b-axis measurement was measured to stimulate the way a particle drops through a sieve opening. This was done to better correlate the wolman counts with bulk samples

Wolman counts were conducted at the same site as the bulk sampling. Wolman counts (grid-by-number) and Surface bulk samples (volume-by-weight) are roughly equivalent. We applied no conversion factor to compare the two sampling methods, as recommended by Church et al (1987) although there is a considerable amount of controversy surrounding this subject.

Wolman counts do not adequately sample the finer sediments. We lumped all Wolman size fractions with a phi of 0 (1-millimeter) and finer in the 0-size catagory. Wolman surface counts are not equivalent to subsurface bulk samples in an armored-bed stream, although conversion factors or graphs can be developed that allow this comparison.

Statistical parameters, graphs, and curves are presented in Table IV and are also shown on the Wolman Sample Data Sheets in Appendix ____.

Table 22. Wolman Sampling Data Sheet

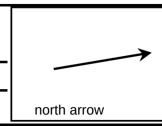
DATE: 10/18/02, 1:00 pm RM: 66.7 REACH: Low-flow SAMPLE CODE: WS - 102

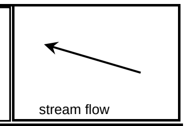
PROJECT: FERC Feather River SP-G2 LOCATION: Hatchery Riffle

SAMPLING CREW: Dave Forwalter, Glen Gordon, Clint Andreason

COMMENTS: Adjacent to WS1-2 sampling location

GRID SIZE: HORIZ: 5.0 feet GPS Coords: Northing: 2314404.9
(cell dimensions) VERT: 5.0 feet (Zone 2, NAD 83) Easting: 6687372.4





Wolman Sampling Raw Data (millimeters)

0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
5																				
10																				
15																				
20																				
25																				
30																				
35																				
40											69	156								
45				214	112	85	132	204	150	45	156	232	94	149	80					
50				145	108	28	255	113	202	75	195	89	60	78	124					
55				195	173	51	182	101	201	14	49	180	178	60	177					
60				28	157	79	193	260	265	223	220	48	143	59	56					
65				225	215	112	70	193	215	80	145	73	260	215	54					
70				296	250	32	13	85	152	163	140	73	128	162	92					
75				178	51	178	123	235	101	55	190			67	109					
80				48	167	236	180	263	70	100	160	49	178	33	68					
85				182	82															
90				120	204															
95																				
100																				
105																				
110																				
115																				
120																				
125																				
130																				
135																				
140																				
145																				
150																				

= not sampled | 112 = surface sample | 39 = underwater sample (or sitting in water) | = bedrock

★ = GPS reference point | = tape baseline(s)

Table 22. Wolman Sampling Data Sheet

Wolman Conversion (phi)

0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
5																				
10																				
15																				
20																				
25																				
30																				
35																				
40											7	8								
45				8	7	7	8	8	8	6	8	8	7	8	7					
50				8	7	5	8	7	8	7	8	7	6	7	7					
55				8	8	6	8	7	8	4	6	8	8	6	8					
60				5	8	7	8	9	9	8	8	6	8	6	6					
65				8	8	7	7	8	8	7	8	7	9	8	6					
70				9	8	5	4	7	8	8	8	7	8	8	7					
75				8	6	8	7	8	7	6	8			7	7					
80				6	8	8	8	9	7	7	8	6	8	6	7					
85				8	7															
90				7	8															
95																				
100																				
105																				
110																				
115																				
120																				
125																				
130																				
135																				
140																				
145																				
150																				

Table 23. Wolman Sample Statistics

Year	Sample	Actual RM	D95	D84	D50	Dg	D16	D5	phi(g)	skewness	kurtosis
2003	WS-BS-20 60ft	48.68									
2003	WS-BS-20 0ft	48.68									
2003	WS-BS-18 115ft	52.30									
2003	WS-BS-18 0ft	52.32	124.25	103.8	63.5	56.2	31.3	18.8		0.34	-0.49
2003	WS-BS-17 70ft	53.63									
2003	WS-BS-17 0ft	53.62	152.75	119.7	71.0	52.9	21.9	7.8		0.44	-0.41
2003	WS-BS-14 155ft	54.66									
2003	WS-BS-14 0ft	54.63									
2003	WS-BS-11 80ft	58.40									
2003	WS-BS-11 0ft	58.41									
2003	WS-BS-10	59.49									
2003	WS-BS-02B us rb	65.77									
2003	WS-BS-02B ds rb	65.76									
2003	WS-BS-02A us center	65.77									
2003	WS-BS-02A ds center	65.76									
2003	WS-BS-01	66.03									
1982	WS-74	61.24	195.0	150.0	94.0	82.2	45.0	23.5	1.80	-0.22	0.76
1982	WS-73	61.60	135.0	100.0	58.0	41.2	17.0	9.2	2.40	-0.42	0.48
1982	WS-72	62.76	125.0	96.0	58.0	40.4	17.0	9.6	2.40	-0.42	0.48
1982	WS-71	44.39	60.0	47.0	33.0	21.7	10.0	1.0	2.20	-0.54	1.60
1982	WS-70	44.82	43.0	35.0	21.0	18.3	9.6	2.5	1.90	-0.21	1.20
1982	WS-69	46.10	73.0	54.0	31.0	29.4	16.0	5.0	1.80	-0.09	0.25
1982	WS-68	46.22	87.0	70.0	45.0	39.2	22.0	11.0	1.80	-0.24	0.79
1982	WS-67		82.0	66.0	40.0	35.4	14.0	11.0	1.90	-0.19	0.61
1982	WS-66	47.27	70.0	51.0	29.0	25.7	13.0	6.4	2.00	-0.17	0.75
1982	WS-65	47.49	50.0	35.0	12.0	17.3	8.6	7.0	2.00	0.03	0.40
1982	WS-64	47.94	105.0	74.0	46.0	40.0	21.5	6.7	1.90	-0.23	0.28
1982	WS-63	47.97	100.0	78.0	45.0	38.5	19.0	5.9	2.00	-0.22	0.18
1982	WS-62b	48.48	105.0	81.0	51.0	47.6	28.0	14.0	1.70	-0.13	0.90
1982	WS-62a	48.33	89.0	70.0	45.0	30.2	13.0	2.0	2.30	-0.48	1.30
1982	WS-61	48.32	100.0	78.0	47.0	31.8	13.0	2.0	2.40	-0.43	1.20
1982	WS-60	48.60	37.0	28.5	16.5	14.7	7.6	2.6	1.90	-0.17	1.00
1982	WS-59	48.62	54.0	40.0	22.0	19.6	9.6	3.4	2.00	-0.16	0.94
1982	WS-58	48.64	84.0	68.0	36.0	31.4	14.5	10.0	2.20	-0.18	0.38
1982	WS-57	48.66	84.0	68.0	35.0	27.3	11.0	2.0	2.50	-0.27	1.10
1982	WS-56	49.09	82.0	66.0	35.0	23.0	8.0	2.6	2.90	-0.40	0.64
1982	WS-55	49.37	97.0	72.0	45.0	35.5	17.5	8.0	2.00	-0.34	0.76
1982	WS-54	49.34	97.0	72.0	38.0	30.0	12.5	4.5	2.40	-0.27	0.75
1982	WS-53	49.33	90.0	72.0	46.0	38.9	21.0	11.0	1.90	-0.28	0.71
1982	WS-52		80.0	66.0	33.5	29.3	13.0	6.6	2.30	-0.17	0.54
1982	WS-51		98.0	74.0	35.0	32.2	14.0	9.0	2.30	-0.10	0.44
1982	WS-50	49.53	74.0	44.0	22.0	16.1	5.9	2.0	2.70	-0.31	0.80
1982	WS-49	49.52	94.0	67.0	35.0	36.6	20.0	10.0	1.80	0.74	0.85
1982	WS-48	51.97	74.0	54.0	25.0	24.9	11.5	6.0	2.20	0.00	0.62
1982	WS-47	52.23	82.0	66.0	38.0	26.6	10.8	3.5	2.50	-0.39	0.74
1982	WS-46	52.24	150.0	110.0	66.0	52.4	25.0	7.8	2.10	-0.31	0.21
1982	WS-45	52.26	64.0	47.0	27.0	23.0	11.3	5.0	2.10	-0.22	0.78
1982	WS-44	52.91	149.0	110.0	66.0	56.5	29.0	9.1	1.90	-0.23	0.23
1982	WS-43b	52.98	107.0	81.0	48.0	33.2	14.0	1.0	2.40	-0.40	1.66
1982	WS-43a	53.58	150.0	119.0	74.0	65.5	36.0	18.0	1.80	-0.21	0.77
1982	WS-42		100.0	74.0	48.0	44.3	26.5	17.0	1.70	-0.16	0.73
1982	WS-41	54.56	145.0	108.0	66.0	58.8	32.0	10.0	1.80	-0.19	0.24
1982	WS-40	54.55	130.0	96.0	58.0	50.9	27.0	15.0	1.90	-0.21	0.70
1982	WS-39	54.75	155.0	110.0	46.0	42.6	16.5	9.0	2.60	-0.08	0.50
1982	WS-38	54.79	74.0	54.0	31.0	27.0	13.5	5.2	2.00	-0.20	0.92
1982	WS-37	55.74	82.0	66.0	40.0	35.0	18.5	11.0	1.90	-0.22	0.58
1982	WS-36	55.81	160.0	108.0	66.0	58.3	31.5	17.0	1.90	-0.20	0.82
1982	WS-35	56.09	89.0	72.0	48.0	38.4	20.5	9.0	1.90	-0.35	0.82
2003	WS-34 210ft	56.35									
2003	WS-34 0ft	56.30	168.85	130.1	78.0	63.3	30.6	19.4		0.71	0.33
1982	WS-34	56.31	165.0	132.0	66.0	49.4	18.5	11.0	2.70	-0.29	0.38

Table 23. Wolman Sample Statistics

1982	WS-33	56.37	210.0	129.0	68.0	63.2	31.0	17.0	2.00	-0.10	0.76
1982	WS-32	56.55	120.0	84.0	45.0	37.8	17.0	11.5	2.20	-0.22	0.48
1982	WS-31	56.57	100.0	76.0	41.0	28.2	10.5	3.0	2.70	0.38	0.77
1982	WS-30	56.71	105.0	83.0	38.0	47.3	27.0	16.0	1.80	0.36	0.68
1982	WS-29	56.93	60.0	39.0	17.0	18.0	8.3	2.6	2.20	0.07	0.28
1982	WS-28	57.20	180.0	120.0	62.0	45.1	17.0	5.6	2.70	-0.32	0.78
1982	WS-27	57.20	120.0	92.0	31.0	41.0	18.3	12.0	2.20	0.27	0.42
1982	WS-26	57.38	82.0	63.0	39.0	32.7	17.0	9.8	1.90	-0.27	0.62
1982	WS-25	57.39	270.0	185.0	107.0	94.7	48.5	14.0	2.00	-0.18	1.20
1982	WS-24	58.40	160.0	110.0	70.0	64.2	37.5	20.0	1.70	-0.16	0.93
1982	WS-23	58.40	130.0	90.0	43.0	37.3	15.5	8.9	2.40	-0.16	0.52
1982	WS-22	57.16	190.0	108.0	72.0	63.1	36.5	25.0	1.70	-0.24	0.85
1982	WS-21	63.46	110.0	81.0	44.0	59.7	8.0	2.6	1.60	1.00	5.20
1982	WS-20	63.47	150.0	106.0	69.0	48.8	22.5	11.5	2.20	-0.45	0.66
1982	WS-19	63.48	170.0	120.0	63.0	49.0	20.0	3.5	2.40	-0.28	1.20
1982	WS-18	58.26	70.0	53.0	33.0	24.1	11.0	3.3	2.20	-0.40	0.94
1982	WS-176	60.07	150.0	113.0	56.0	48.7	21.0	8.0	2.30	-0.17	0.74
1982	WS-175	61.01	115.0	90.0	56.0	42.4	20.0	3.5	2.10	-0.37	1.32
1982	WS-174	61.94	140.0	105.0	69.0	57.4	31.4	19.0	1.80	-0.30	0.65
1982	WS-173	61.96	260.0	170.0	80.0	74.9	33.0	12.0	2.30	-0.08	0.88
1982	WS-172	62.78	98.0	72.0	42.0	32.0	14.0	4.0	2.30	-0.34	0.95
1982	WS-171	44.78	84.0	56.0	29.8	28.2	14.2	4.0	2.00	-0.08	1.20
1982	WS-170	44.85	45.0	38.0	27.0	21.4	12.0	4.0	1.80	-0.41	1.10
1982	WS-17	58.39	170.0	117.0	70.0	56.2	27.0	10.0	2.10	-0.30	0.93
1982	WS-169	44.89	58.0	39.0	22.3	31.6	12.0	6.0	1.80	0.05	0.92
1982	WS-168	45.24	69.0	48.0	25.0	21.5	9.6	3.3	2.20	-0.19	0.89
1982	WS-167	46.13	80.0	65.0	34.0	29.8	13.7	8.0	2.20	-0.17	0.48
1982	WS-166	46.45	70.0	54.0	34.0	27.5	14.0	4.0	12.00	-0.31	1.10
1982	WS-165	46.46	105.0	74.0	40.0	33.9	15.5	4.8	2.20	-0.21	0.22
1982	WS-164	47.99	66.0	47.0	30.5	28.3	17.0	4.0	1.70	-0.15	1.76
1982	WS-163	47.96	58.0	43.7	28.0	24.7	14.0	8.4	1.80	-0.28	0.70
1982	WS-162	49.36	100.0	76.0	48.0	39.9	21.0	11.5	1.90	-0.29	0.68
1982	WS-161AB		72.0	54.0	29.5	26.0	12.5	2.3	2.10	-0.17	1.40
1982	WS-160	48.56	80.0	64.0	34.0	31.0	15.0	4.0	2.10	-0.13	1.10
1982	WS-16	58.47	105.0	84.0	56.0	42.0	21.0	10.0	2.00	-0.42	0.70
1982	WS-159	48.62	78.0	62.0	37.0	23.5	8.9	4.0	2.60	-0.47	0.53
1982	WS-158	48.64	90.0	74.0	50.0	39.4	21.0	6.6	1.90	-0.38	1.10
1982	WS-157	49.13	61.0	44.3	26.5	24.0	13.0	6.9	1.80	-0.16	0.78
1982	WS-156	49.12	74.0	56.0	33.0	29.9	16.0	8.0	1.90	-0.16	0.78
1982	WS-155		74.0	57.0	29.0	25.0	11.0	6.8	2.30	-0.18	0.45
1982	WS-154	49.32	85.0	70.0	45.0	38.3	21.0	10.0	1.80	-0.27	0.78
1982	WS-153		105.0	78.0	47.0	42.4	23.0	14.0	1.80	-0.17	0.65
1982	WS-152	49.36	59.0	47.0	32.5	23.5	11.8	4.0	2.00	-0.47	0.95
1982	WS-151	49.45	70.0	45.0	19.0	19.2	8.2	2.4	2.40	0.01	0.98
1982	WS-150	52.03	84.0	67.0	37.0	27.6	11.4	5.2	2.40	-0.33	0.57
1982	WS-15	59.08	120.0	94.0	60.0	52.2	29.0	17.0	1.80	-0.24	0.66
1982	WS-149	52.04	100.0	82.0	52.0	42.9	22.4	10.0	1.90	-0.30	0.77
1982	WS-148	52.21	105.0	82.0	55.0	42.8	22.3	10.5	1.90	-0.39	0.77
1982	WS-147	52.22	130.0	97.0	60.0	38.1	15.0	8.7	2.50	-0.49	0.45
1982	WS-146	52.27	82.0	66.0	40.0	36.3	20.0	8.0	1.80	-0.16	0.95
1982	WS-145	52.27	64.0	36.0	17.0	17.2	8.2	1.5	2.10	0.01	1.54
1982	WS-144	52.96	100.0	73.0	45.0	41.9	24.0	16.0	1.70	-0.13	0.65
1982	WS-143	53.57	100.0	77.0	40.0	31.6	13.0	4.0	2.40	-0.26	0.81
1982	WS-142	53.61	140.0	105.0	68.0	61.5	36.0	22.0	1.70	-0.19	0.73
1982	WS-141	54.29	150.0	110.0	64.0	48.1	21.0	11.0	2.30	-0.35	0.58
1982	WS-140	54.36	130.0	100.0	67.0	51.5	26.5	10.0	1.90	-0.40	0.93
1982	WS-14	59.12	120.0	88.0	52.0	46.9	25.0	14.0	1.90	-0.16	0.71
1982	WS-139	54.60	115.0	87.0	49.0	40.0	18.4	11.0	2.20	-0.26	0.51
1982	WS-138	54.59	84.0	68.0	40.5	31.6	14.7	7.0	2.20	-0.32	0.62
1982	WS-137	54.60	150.0	114.0	64.0	60.4	32.0	22.5	1.89	-0.09	0.49
1982	WS-136	55.69	83.0	69.0	45.0	37.1	20.0	10.5	1.86	-0.31	0.67
1982	WS-135	55.82	120.0	98.0	68.0	59.4	36.0	16.0	1.60	-0.28	1.01
1982	WS-134	56.39	115.0	86.0	43.0	29.3	18.0	9.0	2.20	-0.11	0.63
1982	WS-133	56.59	105.0	77.0	42.5	34.4	15.4	10.0	2.30	-0.26	0.46
1982	WS-132	56.60	110.0	85.0	65.0	47.0	26.0	11.0	1.80	-0.55	0.94

Table 23. Wolman Sample Statistics

1982	WS-131	56.60	120.0	89.0	50.0	44.7	22.5	13.0	2.00	-0.16	0.62
1982	WS-130	56.72	150.0	105.0	40.0	27.5	7.2	1.7	3.80	-0.28	0.67
1982	WS-13	58.66	160.0	130.0	76.0	57.0	25.0	12.5	2.30	-0.35	0.55
1982	WS-129	56.91	120.0	91.0	54.0	45.2	22.5	13.0	2.00	-0.25	0.59
1982	WS-128	57.40	200.0	160.0	77.0	73.8	34.0	17.0	2.20	-0.06	0.59
1982	WS-127	58.43	150.0	100.0	53.0	44.7	20.0	6.5	2.20	-0.21	0.95
1982	WS-126	58.39	135.0	96.0	49.5	40.4	17.0	9.8	2.40	-0.23	0.52
1982	WS-125	58.39	115.0	86.0	52.0	46.3	24.9	12.0	1.90	-0.19	0.82
1982	WS-124	58.40	110.0	88.0	57.0	40.9	19.0	8.8	2.20	-0.43	0.65
1982	WS-123	57.17	160.0	130.0	76.0	62.4	30.0	17.0	2.10	-0.27	0.53
1982	WS-122	63.57	105.0	79.5	43.0	32.8	13.5	4.0	2.40	-0.31	0.84
1982	WS-121	63.59	100.0	76.0	46.0	38.0	19.0	6.2	2.00	-0.28	1.00
1982	WS-120	58.36	61.0	44.3	23.6	20.4	9.4	4.5	2.20	-0.19	0.68
1982	WS-12	58.68	160.0	131.0	67.0	63.7	31.0	12.0	2.10	-0.07	0.80
1982	WS-119	58.40	135.0	96.0	32.0	31.0	11.2	4.5	3.10	0.90	0.50
1982	WS-118	58.48	100.0	55.0	24.5	23.5	10.0	3.0	2.30	-0.05	1.10
1982	WS-117	59.02	70.0	51.0	28.0	24.6	11.9	7.0	2.10	-0.18	0.58
1982	WS-116	59.01	74.0	55.0	32.0	25.4	11.7	6.2	2.20	-0.34	0.60
1982	WS-115	58.78	150.0	117.0	78.0	93.7	45.0	11.6	1.30	0.82	4.76
1982	WS-114	58.85	115.0	88.0	47.0	26.9	8.2	2.6	3.30	-0.47	0.11
1982	WS-113	59.47	82.0	66.0	40.0	32.0	15.5	9.4	2.10	-0.31	0.50
1982	WS-112	59.50	110.0	75.0	37.5	29.4	11.5	6.2	2.60	-0.26	0.53
1982	WS-111	60.75	74.0	56.0	28.0	24.2	10.5	4.7	2.30	-0.17	0.65
1982	WS-110	60.82	150.0	110.0	60.0	45.7	19.0	6.5	2.40	-0.31	0.79
1982	WS-11	58.70	200.0	160.0	107.0	97.1	59.0	37.0	1.60	-0.19	0.69
1982	WS-109	60.87	165.0	135.0	66.0	61.5	28.0	11.4	2.20	-0.09	0.70
1982	WS-108	60.92	160.0	130.0	60.0	53.5	22.0	11.4	2.40	-0.13	0.49
1982	WS-107	60.70	145.0	110.0	72.0	56.5	29.0	9.4	1.90	-0.36	0.17
1982	WS-106	60.64	200.0	164.0	102.0	80.0	39.0	11.2	2.10	-0.34	1.00
1982	WS-105	60.60	93.0	66.0	32.0	23.0	8.0	2.5	2.90	-0.31	0.16
1982	WS-104	60.61	175.0	145.0	84.0	66.0	30.0	10.5	2.20	-0.31	0.79
1982	WS-103	66.30	255.0	190.0	110.0	72.0	27.0	5.0	2.70	-0.44	1.00
2003	WS-102 center of ds side	66.04	260.00	216.6	136.0	113.7	58.5	31.8		0.18	-0.99
1982	WS-102	66.05	255.0	170.0	90.0	77.1	35.0	9.6	2.20	-0.20	1.10
1982	WS-101	66.09	150.0	115.0	69.0	60.0	31.0	2.0	1.90	-0.22	2.30
1982	WS-10	59.45	105.0	80.0	45.0	39.5	19.5	10.0	2.00	-0.18	0.67
1982	WS-09	60.35	160.0	130.0	48.0	45.6	16.0	5.0	2.90	-0.05	0.10
1982	WS-08	60.50	130.0	95.0	58.0	50.6	27.0	11.5	1.90	-0.26	0.93
1982	WS-07	60.48	165.0	133.0	80.0	76.5	44.0	22.0	1.70	-0.08	0.82
1982	WS-06	60.45	170.0	138.0	45.0	53.0	20.5	12.0	2.60	0.17	0.40
1982	WS-05	60.54	170.0	108.0	52.0	49.8	23.0	10.0	2.20	-0.05	0.83
1982	WS-04	66.23	190.0	143.0	61.0	47.0	15.5	4.0	3.00	-0.23	0.74
2003	WS-03 center	65.14									
1982	WS-03	66.14	180.0	128.0	39.0	43.8	15.0	4.6	2.90	-0.28	0.71
1982	WS-02	66.78	90.0	74.0	51.0	34.4	16.0	3.7	2.20	-0.51	1.10
1982	WS-01	66.77	72.0	53.0	28.5	22.8	9.8	4.5	2.30	-0.27	0.64
2003	WS BS-NewSite in river	59.97									
2003	WS BS-NewSite edgebank	59.97									
2003	WS BS-05 90ft	62.77									
2003	WS BS-05 0ft	62.79									
2003	PS-01	64.27									
2003	MacFarland WS-01 100ft	52.05									
2003	MacFarland WS-01 0ft	52.07									
2003	Junkyard WS-01 125ft	48.67									
2003	Junkyard WS-01 10ft	48.65	92.80	69.0	43.0	38.8	21.4	12.0		0.57	-0.07

Figure 16. Wolman Sampling Grain Size Distribution Curve

(In Progress)

Figure 17. Wolman Sampling Trends, Lower Feather River, Lake Oroville to Honcut Creek

6.1.1.2.3 Spawning Gravel Quality

Much has been written about salmon spawning gravel quality. Quality indicators such as the geometric mean diameter (Shirazi, Seim, and Lewis 1981) and the fredle index (Lotspeich and Everest 1981) are used. The single variable descriptors may not be sufficient if the sample size distribution is not lognormal. For non-lognormal samples, the first and second standard deviation, skewness and kurtosis are required to adequately describe the sample. Most spawning gravel quality indices are specific about the amount of fine sediment that is acceptable, but few specify the amount of allowable cobble and boulder fractions.

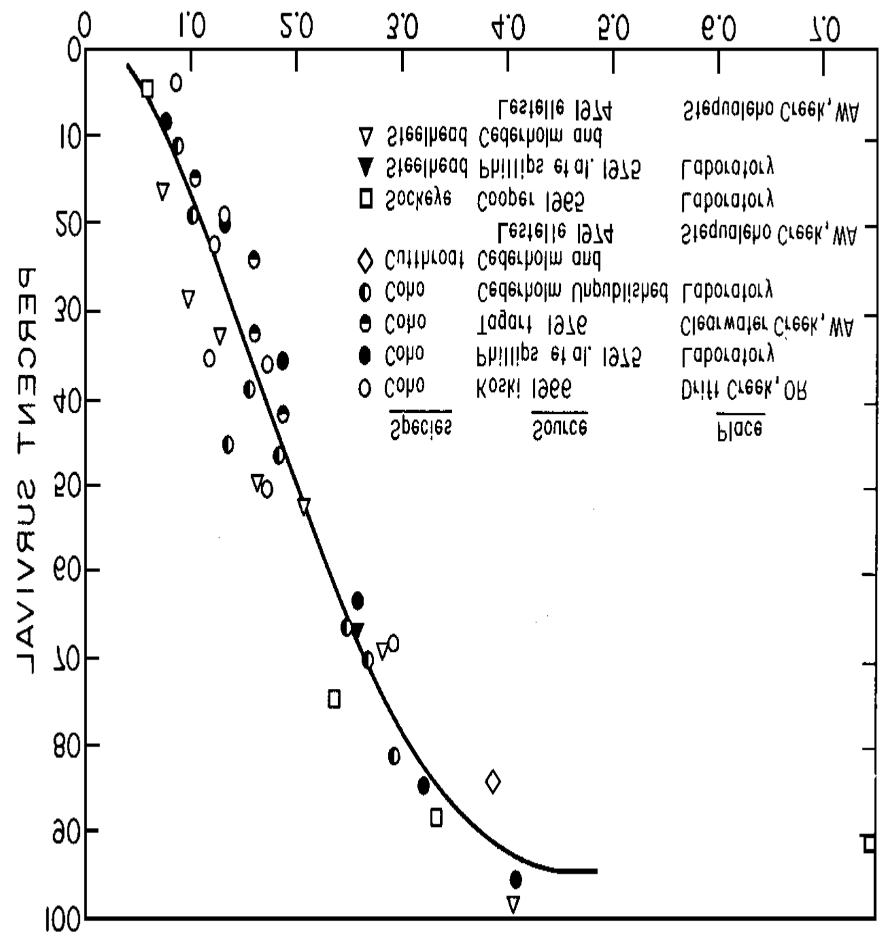


Figure 18. Egg to Alevin Survival as a Function of Gravel Diameter (Shirazi, 1981)

Several researchers have investigated the size range or dimensions of gravels suitable for salmon spawning. Shirazi et al (1981) observed that a ratio of gravel diameter (Dg) to egg diameter (De) provides a strong correlation with embryo survival. Figure 9 shows that egg to alevin survival increases as the Dg/De ratio in redds increases. Maximum survival occurs with a ratio approaching 4. Chinook egg diameters range from 6.3 to 7.9 mm which indicates that maximum survival occurs in redds with a Dg above about 25 mm, or about 0.5 inches.

Table 24 shows the Dg and the Dg\De ratios for all the sieve analyses done during this study.

Table 24. Quality Criteria for Feather River Point Bar Bulk Samples, Lower Feather River from Lake Oroville to Honcut Creek, 1996 Sampling Data

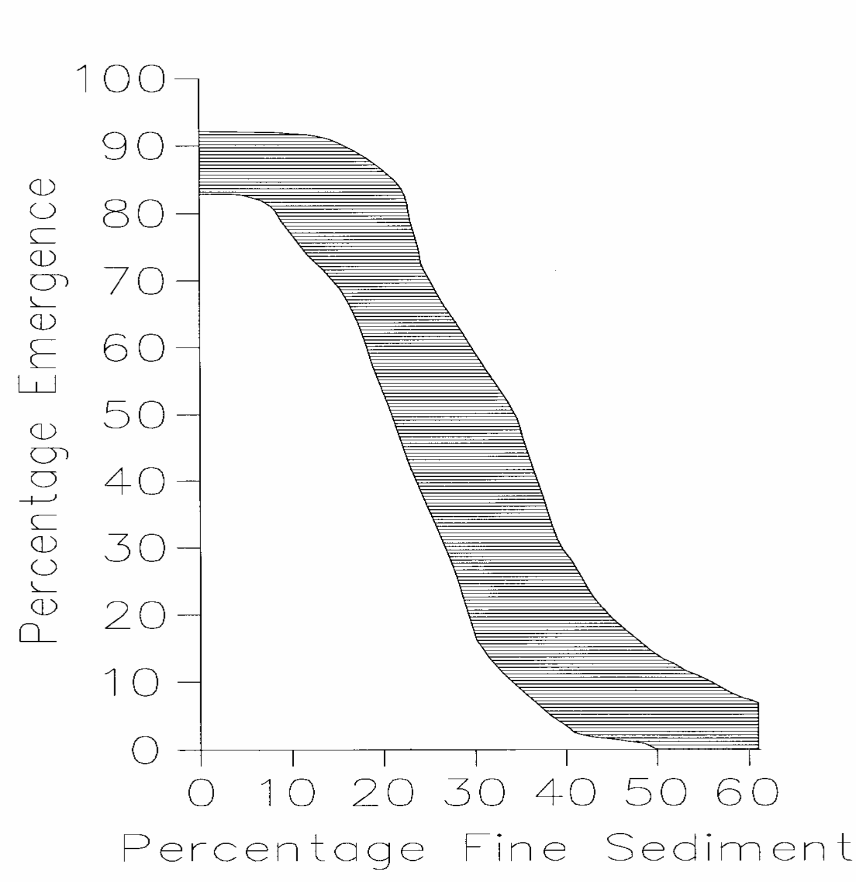


Figure 19. Emergence as a Function of Fine Sediment

The Dg/De ratios for this study range from ___ to ____, suggesting that although the gravel meets embryo survival criteria for fine sediment, it may be too coarse.

The permeability of the substrate surrounding the eggs in part determines the rate and volume of water flowing through the redd. Substrate permeability is a critical factor in egg and alevin survival because dissolved oxygen is brought to the developing eggs

Water flowing through the redd, and metabolic wastes are removed from the developing eggs by the flowing water (Bell 1986).

Permeability is considered high (McNeil and Ahnell 1964) when the bottom materials contain less than 5 percent by volume of particles passing through a sieve opening dimension of 0.8 mm. According to McNeil and Ahnell, if the volume of particles passing the 0.8 mm aperture exceeds fifteen percent, permeability is low. Table V shows the particles passing the 0.8 mm aperture of the spawning gravel samples. Seventeen samples, or 85 percent, have high permeability and none have low.

Particle sizes that reduce embryo survival and impede emergence have been defined as those less than 6.4 mm (0.25 inch) (Bjornn and Reiser 1991). According to Kondolf (1993), sediment particles less than 1 mm (medium sand) will reduce the permeability of spawning gravel. Kondolf adds that the gravel must be free of interstitial sediment less than 3 mm (coarse sand) that would prevent fry emergence.

According to Bjornn and Reiser (1991), upwards of 20 percent of the particles can be less than 6.35 mm in diameter without significantly reducing embryo survival. The effect of fine sediment on fry emergence is shown in Figure 10.

Table ___ shows the percent of each bulk sample finer than 6.4 mm. Two of the samples were more than 20 percent. The average of all the samples was about 11 percent, ranging from 1.6 to 22.Dimensions of acceptable spawning gravel sizes based on percent by volume are shown in Table VI (Puckett and Hinton 1974).The size range and volume of gravel was based on samples taken from Chinook salmon redds in the Eel River.

Table 25. Suitable Spawning Gravel for Chinook Salmon

TABLE VI
Suitable Spawning Gravel for Chinook Salmon

CENTIMETERS	GRAVEL SIZE (INCHES)	PERCENT BY VOLUME
15.2 to 30.5	6 to 12	30 or less
7.6 to 15.2	3 to 6	10 or more
2.5 to 7.6	1 to 3	50 or less
1.3 to 2.5	0.5 to 1	20 or less
0.4 to 1.3	0.16 to 0.5	20 or less
0.04 to 0.4	0.015 to 0.16	20 or less

The three smaller sizes in combination should not exceed 50%
Source: Puckett and Hinton, 1974.

The maximum size sediment that the salmon can tolerate appears to be a function of two variables. First the maximum sizes that the salmon can physically move during redd construction and second, the size where the eggs are no longer retained but washed out of the interstices between the particles. We could not find any criteria on either of these two variables.

Appendix ____ shows spawning gravel criteria plotted on gradation curves. The shaded area is the acceptable range of spawning gravel sizes developed from published criteria. The upper part of the curve follows the lognormal distribution of Shirazi et al (1981), the lower portion of the curve uses the maximum acceptable fines as described by Bjornn and Reiser (1991).

Spawning gravel that plots toward the center of the shaded area is the most suitable. Spawning gravel that plots towards the edges are less suitable, and gravel that plots outside the shaded area are unacceptable based on these criteria.

6.1.1.2.4 River Withdrawals and Return Flows

"Locations and volumes of withdrawals and return flows to the river will be assessed for potential effects to geomorphic processes."

(In Progress)

6.2 ANALYSES

(In Progress)

6.2.1 Relationship between Surface and Bulk Sediments

"Compare and develop mathematical relation between the two sampling methods."

(In Progress)

6.2.2 Spawning Riffle Comparisons

(In Progress)

6.2.3 Armoring Downstream of Dams

"A comparison of the Median grain size determined by the two different methods is a measure of the degree of armoring."

On the Feather River, the suitability of salmon spawning habitat is degraded by excessively coarse gravel and cobbles immediately downstream of Oroville Dam to below the Highway 162 Bridge. The altered hydraulic regime resulting from the construction of Oroville
Dam has eliminated smaller gravel from the upper spawning riffles. The altered flow regime resulting from reservoir operation, coupled with lack of gravel recruitment enhances the erosive and scouring capacity of the river at these points, thereby removing size fractions suitable for spawning.

Most of the depositional features found in this reach are probably relict structures dating back to before the completion of Oroville Dam in 1967. Pre-Project flood flows would scour the channel, islands, and point bars down to a coarse surface consisting of cobbles and boulders. More moderate flows would then transport in finer sediments and sculpture the depositional features. These moderate flows would deposit a layer of gravel on islands, riffles, and point bars.

Under the post-Oroville Dam hydraulic regime, if undisturbed, point bars and islands would not interact with the river; they would not erode during high flows and no gravel would be available to deposit on these features. The features generally are armored with sediment that is too coarse for the present river to transport.

6.2.4 Historic Changes in Gravel Size

"Gradation curves for each riffle will be prepared and compared to similar investigations done in 1980, 1982, and 1997. Trend lines showing the changes in gravel size distribution will be prepared. "

Historic Changes in Gravel Size

Bulk and surface sampling were done in the study reach by DWR (1982) for the Feather River Spawning Gravel Baseline Study. Twenty bulk samples and 176 surface samples were taken at the head of point bars. Since 1982, however, probably over 10,000 cubic yards of gravel have been placed in the river at some sites. The gravel placement adds a layer of confusion to trend analysis and to comparison of 1982 and 1996 surface and bulk samples.

We compared the statistical parameters of the surface Wolman samples and bulk samples for 1982 and 1996. The most marked trend is the continued coarsening of the gravel in the upper five riffles of the study reach after the periodic importation and placement of spawning size gravel.

In contrast with the conditions in the upper-most riffles, recent erosion of banks and levees at riffle seven, and subsequent recruitment of fines, has re-infused the middle section of the study reach with a load of mixed-size movable gravel material. Prior encroachment of riparian vegetation adjacent to the next riffles is slowing the movement of this sediment load and causing constrictions where fines are being deposited. This constriction in the channel may have contributed to the levee blowout in spring 1995.

Below the Afterbay river outlet, surface and bulk sampling shows that most riffle sites have gravel that meets spawning criteria. Water flow and depth factors must play a larger role in site preference in this river reach.

7.0 LOCATE AND RESURVEY HISTORIC CROSS-SECTIONS

7.1 METHODOLOGY AND RESULTS

"This part consists of surveying cross-section locations in the river below the dam. Cross-sections have been surveyed in the low flow reach in the past. As many of these as possible will be re-established, and additional cross-section locations surveyed to provide sufficient spacing for the study needs. Cross-sections will also be established below the Thermalito outfall, for some distance downstream and with spacing dependent on need. The end-points will be permanently marked using steel pipe set in concrete monuments and surveyed using GPS. Each cross-section location will have a photo point, and additional photo points will be established in critical areas.

Field characteristics of sediment, floodplain, and riparian condition will provide the basis for transect selection for detailed study. The study sites may include sensitive sites with potential project-related impacts, representative sites for the range of identified stream types, stream gage locations, and reference reaches."

7.1.1 Locate Existing Cross-Sections

"Establish baselines, locate benchmarks and existing cross-section locations, and set monuments. Survey monuments using GPS."

(In Progress)

Table 26. Historical Cross Sections along Lower Feather River

(shaded) = data set to be used with Fluvial-12 sediment transport model

FLUVIAL-12 MODEL RUNS	DATE	AGENCY	TITLE	River mile (start)	River mile (end)	# of cross-sections
pre-Oroville Dam	1909	United States. War Dept and United States. Army. Corps of Engineers	Feather River, California	0.0	67.0	331
	1924	United States. Army. Corps of Engineers		6.9	24.5	13
	1925	United States. Army. Corps of Engineers	Sacramento River, California, revision of flood control project : showing profiles			
	1939	United States. Army. Corps of Engineers	Preliminary Examination			
	1965	California. Dept. of Water Resources	Determination of the Channel Capacity of the Feather River,	16.0	50.5	37
post-Oroville Dam	1968	United States. Army. Corps of Engineers. Sacramento District and California. State Reclamation Board	Flood plain information, Feather and Yuba Rivers, Marysville-Yuba City, California : prepared for the California State Reclamation Board ... et al			
	1968	United States. Army. Corps of Engineers and California. Reclamation Board	Flooded areas, Nicolaus, California			
	1968	United States. Army. Corps of Engineers and California. Reclamation Board	Floods, Maryville-Yuba City, California			
	1968	California. Dept. of Water Resources - Central District	Progress Report of Documentation of the Feather River Floodplain Conditions	11.5	53.2	10
	1972	California. Dept. of Water Resources - Central District	Feather River : Safety			
	1972	United States Geological Survey	Determination of Channel Changes in the Feather River	44.7	67.2	71
	1978	United States Geological Survey	Sediment Transport in the Feather River			
	1981	California. Dept. of Water Resources -Northern District	Spawning Gravel Study	49.6	66.8	158
	1983	California. Dept. of Water Resources -Northern District	Spawning Gravel Study (Moe's Ditch)	66.5	66.8	42
	1986	United States. Army. Corps of Engineers	Feather River : Oroville Dam to Sacramento River			
	1990	United States. Army. Corps of Engineers. Sacramento District	Yuba River Investigation	5.0	29.3	37
	1991	California. Dept. of Water Resources -Northern District	IFIM Study (unpublished data)	45.5	66.6	34
	1992	United States. Army. Corps of Engineers. Sacramento District		6.9	27.3	15
	1994	California. Dept. of Water Resources -Central District	IFIM Study (unpublished data)	0.5	44.0	6
	1998	United States. Army. Corps of Engineers. Sacramento District and California. Reclamation Board	Yuba River Basin investigation, California : final feasibility report and appendixes			
	1999	United States. Army. Corps of Engineers. Sacramento District and California. Reclamation Board	Sacramento River Comprehensive Study - UNET Data			
2007 to 2057	2002	California. Dept. of Water Resources -Northern District	Re-surveys of IFIM cross-sections (unpublished data)	44.7	67.2	12 of 34

Table 27. IFIM Cross-sections

AR-LB-CP-3	monument found and GPS surveyed in 2002
Transect 1	entire transect GPS surveyed in 2002

River Mile	Riffle/Feature	Cross-section	Length of Cross-section	DWR Geology Right Bank Point	EASTING	NORTHING	DWR Geology Left Bank Point	EASTING	NORTHING
	Table Mountain Bridge								
	Hatchery Riffle	Transect 1	563.00	I - 1			I - 2		
66.4	Auditorium Riffle	Transect 3	492.89	I - 3			I - 4		
	Auditorium Riffle	Transect 2	504.22	I - 5			I - 6		
	Auditorium Riffle	Transect 1	541.55	I - 7			I - 8		
65.8	Bedrock Park Riffle								
	Bedrock Park Riffle								
	Highway 70 Bridge								
	Highway 70 Bridge								
	River Bend Park								
	River Bend Park								
64.5	Highway 162 Bridge	Transect 1		I - 9			I - 10		
63.8	Mathews Riffle	Transect 3		I - 11			I - 12		
	Mathews Riffle	Transect 2		I - 13			I - 14		
	Mathews Riffle	Transect 1		I - 15			I - 16		
63.4	Aleck Riffle	Transect 3	191.42	I - 17			I - 18		
	Aleck Riffle	Transect 2	198.89	I - 19			I - 20		
	Aleck Riffle	Transect 1	393.60	I - 21			I - 22		
62.7	Great Western Riffle	Transect 1	280.61	I - 23			I - 24		
61.1	Robinson Riffle	Transect 3	392.95	I - 25			I - 26		
	Robinson Riffle	Transect 2	419.08	I - 27			I - 28		
	Robinson Riffle	Transect 1	417.93	I - 29			I - 30		
60.8	Steep Riffle								
	Steep Riffle								
60.6	Weir Riffle	Transect 2	324.15	I - 31			I - 32		
	Weir Riffle	Transect 1	299.52	I - 33			I - 34		
60.4	Gateway Riffle								
	Gateway Riffle								
58.7	Sutter Butte Riffle			I - 35			I - 36		
	Sutter Butte Riffle								
57.5	Conveyor Belt Riffle	Transect 2LC	162.60	I - 37A			I - 37B		
	Conveyor Belt Riffle	Transect 2RC	196.20	I - 38A			I - 38B		
	Conveyor Belt Riffle	Transect 1	467.80	I - 39			I - 40		
56.7	Hour Riffle	Transect 3	342.10	I - 41			I - 42		
	Hour Riffle	Transect 2	362.00	I - 43			I - 44		
	Hour Riffle	Transect 1	346.23	I - 45			I - 46		
55.2	Keister Riffle								
	Keister Riffle								
54.8	Goose Riffle	Transect 3	186.93	I - 47			I - 48		
	Goose Riffle	Transect 2	284.71	I - 49			I - 50		
	Goose Riffle	Transect 1	265.53	I - 51			I - 52		
	Goose Backwater	Transect 1	492.40	I - 53			I - 53.5		
	Goose Backwater	Transect 1		I - 53.5			I - 54		
53.7	Big Riffle	Transect 2	298.10	I - 55			I - 56		
	Big Riffle	Transect 1	257.70	I - 57			I - 58		
	Macfarland Riffle								
	Macfarland Riffle								
	Gridley Bridge								
	Gridley Bridge								
50.3	Gridley Riffle								
	Gridley Riffle								
	Shallow Riffle	Transect 3		I - 59			I - 60		
	Shallow Riffle	Transect 2A		I - 61			I - 62		
	Shallow Riffle	Transect 2B		I - 62			I - 63		
	Shallow Riffle	Transect 1		I - 64			I - 65		
46.7	Herringer Riffle	Transect 3		I - 66			I - 67		
	Herringer Riffle	Transect 2		I - 68			I - 69		
	Herringer Riffle	Transect 1		I - 70			I - 71		
	Honcut Creek								